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The Impact of Unexpected Macro-Disturbances on Exchange Rates in Monetary Models*

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The basic thrust of monetary approaches (asset approaches) involves the assertion that the exchange rate, as the relative price of two monies, is determined primarily by the relative supplies and demands for these national monies (see [4, 5, 6, 7, 9, 10, and 12]). Since monies are viewed as assets to hold, the expectation of the future price of monies also plays an important role in the exchange rate determination. Thus, in Michael Mussa [21] and John Bilson's [4] formulations, the expected future exchange rate and the "basic determinants" — relative money supplies, relative real incomes, and relative interest rates — become the key variables to explain the exchange rate movements. This work on monetary approaches and the associated empirical estimations have raised three important issues.[1]

The first issue concerns what variables should be considered as the basic determinants of the exchange rate. Given the dissimilarity in economic conditions, financial market structure, and the policy objectives for different countries, it is perceivable that the observed explanatory variables in the empirical context would not possibly have the same explanatory power in the prediction of the exchange rate. Accordingly, a criterion consistent with economic theory and empirical regularity has to be used to assess the variables included in the basic determinants of exchange rate.

The second issue concerns the impact of unexpected disturbances of macroeconomic variables on the exchange rate movements. This is a direct implication from the rational expectations hypothesis. According to "rational expectations" models, since all of the expected changes for each of the basic determinants have been contained in the model to forecast the change of exchange rate, the unexpected change in the exchange rate must correspond to the unexpected changes in the basic determinants. Thus, to examine the exchange rate behavior, as pointed out by Rudiger Dornbusch [10], "we need a model of the unanticipated component of the exogenous variables."

The third issue concerns the efficient market hypothesis. It is acknowledged that there is some degree of similarity inherent in the stochastic behavior between the exchange rates and other asset prices. One would expect that if there were substantial serial correlations involved in the exchange rate changes, it would be possible for economic agents to exploit this correlation profitably. Therefore, it is interesting to examine whether or not the foreign exchange market is efficient in this sense. More specifically, if the market is efficient, all of the impacts of unexpected disturbance should be contemporaneous. This implies that the unexpected changes in exchange rate must be independent of lagged innovations of the basic determinants of exchange rate.[2]

This article addresses the above three issues within the empirical context. Following this introductory section, the second section develops a rational expectations model for analyzing the exchange rate. The third discusses the estimating procedures and presents the empirical results for the countries examined. The fourth section contains the concluding remarks.

THE MODEL

The theory of rational expectations asserts that the participants in the foreign exchange market use all the available information to forecast the expected value of exchange rate. The rationality of expectations implies that

$$E(S_t - S_t^e \mid \phi_{t-1}) = 0, \tag{1}$$

where $E(\ldots)$ is expectation operator, S_t is the spot exchange rate at time t, S_t^e is the one-period-ahead forecast of S_t conditional on the past available information, ϕ_{t-1}, the latter denoting the information set at the end of time $t-1$. Equation (1) assumes that the forecast error for the spot rate has the properties of zero mean and is uncorrelated with the past information contained in ϕ_{t-1}. Specifically, it states that divergences of the actual spot rate from the expected value assessed by the market (unbiased forecast) at the end of $t-1$ reflect mainly "new information" hitting the market for the period from the end of $t-1$ to t. Since this new information was not predictable at the time the market performed optimal forecasts, the unpredictable changes in the exchange rate must correspond to the unpredictable changes embodied in the new information set.[3] Thus, Equation (1) can be rewritten as

$$S_t - S_t^e = (X_t - X_t^e)b + \epsilon_t \text{ or} \tag{2}$$

$$S_t = S_t^e + (X_t - X_t^e)b + \epsilon_t, \tag{3}$$

where a superscript e denotes the market's expectations conditional on all past and known information.[4] X_t is a vector of variables that contains the information relevant to the basic determinants of spot exchange rate; b is a vector of coefficients; and ϵ_t is a serially uncorrelated error process.

In order to generate X_t^e and S_t^e, it is assumed that the stochastic processes generating the time-series on these expected variables in system (3) are covariance stationary and have finite autoregressive order. The best linear unbiased forecast of X_t and S_t, given the information at the end of $t-1$, thus can be constructed in the following fashion:[5]

$$X_t^e \equiv X_t^e = \sum_{g=1}^{k} \beta(g) X_{t-g} + w_t, \tag{4}$$

$$S_t^e \equiv S_t^e = \sum_{j=1}^{n} b_s(j) S_{t-j} + v_t, \tag{5}$$

where w_t and v_t are, respectively, error terms.[6]

As stated earlier, the basic determinants of the exchange rate in monetary models consist of the relative money supplies, relative real incomes, and the relative interest rates. That is, $(X - X^e)_{t-j}$ applies to $(m - m^e)_{t-j}$, $(y - y^e)_{t-j}$, and $(r - r^e)_{t-j}$. Incorporating these elements into (5) and (3), yields

$$S_t = \sum_{j=1}^{n} b_s(j) S_{t-j} + \sum_{j=0}^{n_1} b_m(j)\,(m - m^e)_{t-j} + \sum_{j=0}^{n_2} b_y(j)\,(y - y^e)_{t-j} + \sum_{j=0}^{n_3} b_r(j)\,(r - r^e)_{t-j} + \epsilon_t, \tag{6}$$

where $b_s > 0$, $b_m > 0$, $b_y < 0$, $b_r \lesseqgtr 0$; m and y are the differences (domestic versus foreign) of logs of respective money supplies and real incomes; r denotes the interest rate differential between two countries.[7]

Several comments about Equation (6) are in order. First, my analysis is consistent with the rational expectations model of monetary approaches [4, 21].[8] Coefficient b_m is theoretically positive, and b_y is negative, implying that unanticipated increases (decreases) in domestic relative to foreign money (real income) cause a depreciation of domestic currency.[9] The coefficient b_r appears to have an ambiguous sign, depending on the stickiness of prices. For countries experiencing relatively higher rates of inflation, b_r tends to be positive; for countries with similar rates of inflation, the sign of b_r tends to be negative (see [5, 7, and 12].

Second, market efficiency in the foreign exchange market can be examined in terms of Equation (6). Since, in the optimal forecasting process, all the past and known information relevant to the forecasting of current spot rate has been incorporated into the lagged exchange rate terms, the innovations in current spot rate $(S_t - \sum_{j=1}^{n} b_s(j) S_{t-j})$ should not be serially correlated with the lagged values of $(m - m^e)_{t-j}$, $(y - y^e)_{t-j}$, and $(r - r^e)_{t-j}$. Testing the market efficiency is equivalent to testing the restrictions $b_m(j) = b_y(j) = b_r(j) = 0$, for $j \geq 1$.[10] Rejection of these restrictions implies the existence of adjustment lags although it is not inconsistent with the monetary approaches.

Third, the random walk hypothesis can also be examined by using Equation (6). If the foreign exchange market is characterized as random, it must imply $b_m(j) = b_y(j) = b_r(j) = 0$ for $j \geq 0$; $b_s(1) = 1$ and $b_s(j) = 0$ for $j \geq 2$ with a finite lagged order. The rejection of the maintained hypothesis may mean that the exchange rate behavior follows a pattern with a longer distributed lag or/and reacts less rapidly in response to new information. Thus, it is clear that the random walk hypothesis appears to be a special case in our general specification.

ESTIMATING PROCEDURES AND RESULTS

Equation (6) is the system I use to estimate the exchange rate equation for the UK pound, German mark, Italian lira, and French franc. All the monthly data spanning the time period January 1974 to September 1979 are taken from *International Financial Statistics*.[11] The exchange rate is in natural log and defined as units of particular currency per unit of US dollar. Other variables are the differences of logs of respective national money supplies ($m = \log M - \log M^*$), real incomes ($y = \log Y - \log Y^*$), and interest rates ($r = R - R^*$).

Given the data constructed as mentioned above, I then proceed to generate measures of unexpected changes in the relevant variables that were derived by taking the difference between the actual value and expected value. In order to obtain consistent estimates of expectations, vector autoregressions were employed in the estimations. In particular, the expected values of m, y, and r were estimated by regressing on their own past value with six orders of lags and on the other variables with four orders of lags in a simultaneous equations system. From the forecasting point of view, this method exploits all the information in the series that is relevant for forecasting the future value of the variable. Thus, it represents an optimal forecasting of the expectations.[12]

Having generated the measures of the unexpected-change variables, next one must decide the appropriate random innovations (that is, unexpected changes in the basic determinants) in the information set for the optimal forecast and the optimal length of lags for the chosen innovations. To this end, Hirotugu Akaike [2] and Cheng Hsiao's [16] final prediction error (FPE) criterion has been used to choose the innovations and their orders of lags. Intuitively, the FPE of the estimated equation can be viewed simply as the mean square error of the estimated equation adjusted for degrees of freedom.

The procedures for estimating Equation (6) can be described as follows. First, regress S_t on its past values, S_{t-j}, by varying its orders from 1 to 12 and pick up the order with minimum value of FPE.[13] Second, given the chosen order of S_{t-j} as control variable, then add the innovations — $(m - m^e)_{t-j}$, $(y - y^e)_{t-j}$, and $(r - r^e)_{t-j}$ — with various order of lags. In this manner, one searches for the equation that yields the minimum value of FPE at grand level.

The search results based on minimum FPE for various exchange rates are presented in Table 1. The evidence indicates that the lagged values of exchange rate play a vital role in explaining the exchange rate movements (see the coefficients and the associated t statistics), which is consistent with the findings obtained by Bradford Cornell [9], Richard M. Levich [17], and David Longworth [18]. This result should not be surprising since all the relevant expected factors in the optimal forecasting process have been incorporated into the distributed lagged values of S_t. However, the sum of the coefficients on S_{t-j} below 1 suggests that the lagged values of the spot rate alone may be inadequate to explain the exchange rate movements.[14] This will become clear in investigating the coefficients on the unanticipated components later.[15]

As may be seen from Table 1, the coefficients on the unexpected money supply have the anticipated sign and are statistically significant for the United Kingdom and Germany but nonsignificant for Italy and France. Next, examining the coefficient on real income shows that only the coefficient for Germany is statistically significant, implying that the unexpected changes in real income do not have a significant impact on the prediction of exchange rate. Finally, the coefficient on the interest rate innovation is positive for Italy and negative for Germany and France.[16] The conflict sign on the interest rate coefficient is perhaps due to Italy having a relatively higher inflation rate than Germany and France. Thus, unexpected changes in interest rate differential for Italy reflect most of the unexpected higher inflation variations, resulting in currency depreciation. For Germany and France, the positive real interest rate effect dominates. As a result, a higher interest rate differential leads to currency appreciation.[17]

From this study, it is apparent that the lagged innovations do have a significant impact on the exchange rate movements, although the impacts of innovations vary from one exchange rate to another. Of the countries examined, past information, reflected in lagged innovations involving changes of money supplies, real incomes, and interest rates, appears to be statistically significant for the United Kingdom, Germany, and Italy. This evidence conforms closely to the findings obtained by Yash Mehra and T. C. Chiang [19], who found that adjustments in foreign exchange markets are not instantaneous. The evidence thus suggests that an efficient market hypothesis for the UK pound, Italian lira, and German mark has to be rejected. An exception in this study is the French franc, in which all the lagged innovations are not statistically significant, suggesting that the efficient market hypothesis cannot be rejected.

Two comments should be made in relation to an efficient market. First, our empirical studies indicate that only the United Kingdom and Italy follow a first-order autoregressive process; these cast some doubt on the random walk hypothesis applied to the foreign exchange market. Second, when contemporaneous innovations were included in the estimations, with the exceptions of interest rate innovation for Italy and France, the evidence does not strongly support the view that current innovation plays an important role in explaining the exchange rate movements.

In order to provide further information concerning the impact of lagged and current innovations, I performed the F tests. Using Clive Granger's concept of causality, the F test provides a test of the null hypothesis that the coefficients on lagged innovations are restrained to zero. The F statistics in Table 2 indicate

Table 1

ESTIMATIONS OF CURRENT AND LAGGED INNOVATIONS ON EXCHANGE RATES[a]

Dependent Variable	U.K.		Germany		Italy		France	
Coefficient of Independent Variable	S_t	S_t	S_t	S_t	S_t	S_t	S_t	S_t
C	−0.002 (−0.492)[b]	−0.002 (−0.4)	−0.002 (−0.533)	−0.002 (−0.608)	−0.001 (−0.3)	−0.001 (−0.423)	−0.001 (−0.259)	−0.001 (−0.250)
$b_s(1)$	0.0981* (33.566)	0.981* (32.578)	0.652* (5.074)	0.658* (4.837)	0.965* (24.653)	0.970* (25.5)	0.558* (3.474)	0.509* (3.567)
$b_s(2)$			0.517* (3.160)	0.531* (3.082)			0.564* (3.2031)	0.697* (4.478)
$b_s(3)$			−0.235** (−1.903)	−0.246** (−1.950)			0.107 0.583	0.082 0.513
$b_s(4)$							−0.105 (−0.646)	−0.110 (−0.769)
$b_s(5)$							−0.212 (−1.549)	−0.211** (−1.771)
$b_m(0)$		−0.017 (−0.072)		0.075 (0.372)		−0.235 (−1.147)		0.139 (0.671)
$b_m(1)$	0.871* (3.748)	0.857* (3.582)	0.137 (0.690)	0.177 (0.851)	0.168 (1.211)	0.135 (1.0104)	−0.153 (−0.636)	−0.157 (−0.756)
$b_m(2)$	0.880* (3.729)	0.868* (3.571)	0.221 (1.084)	0.288 (1.245)				
$b_m(3)$			−0.011 (−0.048)	−0.007 (−0.029)				
$b_m(4)$			0.220 (1.006)	0.281 (1.197)				

$b_m(5)$			0.850*	0.800*				
			(3.583)	(3.518)				
$b_y(0)$		−0.126		−0.180		−0.109		0.284
		(−0.747)		(−0.704)		(−1.157)		(1.171)
$b_y(1)$			0.184	−0.158			0.243	0.362
			(−0.756)	(−0.623)			(0.862)	(1.467)
$b_y(2)$			0.074	0.070				
			(0.310)	(0.289)				
$b_y(3)$			−0.609*	−0.553*				
			(−2.566)	(−2.247)				
$b_y(4)$			0.463	0.253				
			(1.433)	(1.053)				
$b_r(0)$		0.015		−0.018		0.054*		−0.241*
			(1.433)	(1.053)		(2.487)		(−4.335)
$b_r(1)$			−0.033**	−0.033**	0.057*	0.065*	−0.079	−0.126
			(−1.829)	(−1.766)	(2.575)	(2.923)	(−1.051)	(−1.007)
$b_r(2)$			0.022	0.023				
			(1.199)	(1.218)				
$b_r(3)$			−0.004	−0.003				
			(−0.198)	(−0.145)				
$b_r(4)$			−0.034**	−0.035**				
			(−1.850)	(−1.852)				
R^2	0.954	0.954	0.884	0.889	0.918	0.928	0.864	0.904
S.E.E.	0.024	0.025	0.025	0.025	0.025	0.024	0.026	0.023
D.W.	1.995	2.013	1.996	2.000	1.974	2.047	2.020	1.982
FPEx10^4	5.291	5.694	6.925	7.332	5.828	5.531	6.619	5.119

[a] $S_t = C + \Sigma b_s(j)S_{t-j} + \Sigma b_m(j)(m - m^e)_{t-j} + \Sigma b_y(j)(y - y^e)_{t-j} + \Sigma b_r(j)(r - r^e)_{t-j} + \epsilon_t$.
[b] The numbers in parentheses are t-statistics.
* Significant at 5% level.
** Significant at 10% level.

Table 2

F STATISTICS FOR THE NULL HYPOTHESIS: COEFFICIENTS ON LAGGED INNOVATIONS ARE ZERO[a]

Country	F-statistics
UK pound	14.340*
German mark	2.822*
Italian lira	5.519*
French franc	0.863

[a] The F statistics are used to test the restriction:
$b_m(j) = b_y(j) = b_r(j) = 0, j = 1 \ldots n.$
$F = (SSR_r - SSR_u)/(df_r - df_u)/(SSR_u/df_u).$
SSR_r and SSR_u are sums of squared residuals from respectively the estimates of the restricted and unrestricted equations; df_r and df_u are the corresponding degrees of freedom.
Restricted equation:
$S_t = C + \Sigma b_s(j) S_{t-j} + \epsilon_t$
Unrestricted equation:
$S_t = C + \Sigma b_s(j) S_{t-j} + \Sigma b_m(j)(m - m^e)_{t-j} + \Sigma b_y(j)(y - y^e)_{t-j} + \Sigma b_r(j)(r - r^e)_{t-j} + \epsilon_t.$
*Significant at the 5% level. Reject the null hypothesis.

that the null hypothesis should be rejected for the United Kingdom, Germany, and Italy, but cannot be rejected for France. The rejection of the hypothesis implies that the lagged innovations involving changes in $(m - m^e)$, $(y - y^e)$, and $(r - r^e)$ have a substantial effect on the exchange rate movements.[18] These findings conform closely to the results obtained in Table 1. The evidence thus consistently indicates that there are adjustment lags existing in the foreign exchange markets for the United Kingdom, Germany, and Italy.[19]

CONCLUDING REMARKS

In this article, I have developed a rational expectations model to examine the exchange rate behavior for the UK pound, German mark, Italian lira, and French franc. I divide the observed macroeconomic variables, unlike conventional monetary models, into both expected-change and unexpected-change components. The empirical evidence presented in this article indicates that the lagged value of exchange rate, which captures the expected-change components of the basic determinants, contains useful information to explain the exchange rate movements. This finding is quite consistent with David Longworth's [18] study on the Canadian dollar.

The empirical results also support the hypothesis that the unexpected changes in the variables of relative money supply, relative real income, and interest rate differential have profound impacts on exchange rate movements.

In addition, my empirical evidence indicates that there are adjustment lags prevailing in the markets for the UK pound, German mark, and Italian lira. Therefore, the efficient market hypothesis does not hold for these three currencies.

NOTES

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1. Some of these issues are raised by Mussa [21] and Dornbusch [10].

2. The concept of efficient market here is consistent with the one defined by Levich [17], Mishkin [20], and Mussa [21]. An excellent discussion can be found in Mussa [21].

3. The terms of unexpected, unpredictable, unanticipated, new information, and innovation are used interchangeably in the literature and, hence, in this article.

4. The formulation closely follows Barro [3], Mishkin [20], Abel and Mishkin [1].

5. Although X_t^e and S_t^e are generated by two separate equations, namely (4) and (5), they both reflect the same information and hence are not necessarily independent of each other. See Note (6).

6. Expectations can be estimated by using vector autoregressive process (Geweke [13], Abel and Mishkin [1], and Mehra and Chiang [19]). In particular, X_{t-g} is a vector of variables (m_{t-g}, y_{t-g}, and r_{t-g}) known at the end of period $t-1$. See text in the following section.

7. It should be noted that both the contemporaneous and lagged values of the basic determinants are included in the right hand side of Equation (6). This expression is directly derived from the optimal forecasting procedure represented by (4). Also, Bilson [5] has presented evidence that lagged values of certain key macro-variables play important roles in the exchange rate determination.

8. If one is interested in a direct test of the rational expectations hypothesis that the unexpected changes in exchange rates are disturbed by the unexpected changes of the exchange rate determinants, one should use Equation (2) to estimate b. However, our main concern here is to measure the unexpected disturbances on the actual exchange rate movements. Accordingly, Equation (6) will be employed in our empirical analysis.

9. A traditional Keynesian model would argue that the sign of b_y is positive. The reason is that an unanticipated increase in domestic real income will cause an increase in the demand for imported goods, leading to a depreciation of domestic currency. As pointed out by the monetary approaches, this traditional Keynesian model is based on the assumption that an increase in the demand-for-money balance due to a rise in real income will be automatically accommodated by the monetary authorities. Thus, this Keynesian neutral policy abstracts the monetary implication in the exchange rate determination.

10. $j = 0$ implies that the contemporaneous terms of $(m - m^e)_t$, $(y - y^e)_t$, and $(r - r^e)_t$ are also included in Equation (6). It should be noted that the significance of these terms is consistent with efficient market hypothesis.

11. The data utilized in this article were only for up to September 1979. The decision was made on the following grounds. First, the Federal Reserve system (Fed) changed its operating procedures from the interest rate target to the monetary-aggregate target on 6 October 1979. Second, accompanying the procedural changes, the definitions of money and, hence, the measures of the money supply were revised abruptly. To maintain the consistency of measuring the money supply, the data for the period post October 1979 were excluded from the estimations. It would be of interest to examine the impact of change in operating procedures on the exchange rate movements. To this end, an intervention model developed by Box and Tiao (*Journal of the American Statistical Association*, 1975) may be used to examine the time series, which would deserve an independent study.

12. The theoretical aspect is discussed in Abel and Mishkin [1] and Geweke [13]. The application can be found in Mehra and Chiang [19].

13. In the literature, the forward rate is widely used as a proxy of the expected future spot rate in modelling expectations (see Edwards [11]). Recently, considerable evidence has indicated that the lagged spot rate is superior to the forward rate. For instance, Cornell [8] found that for the sample period April 1973 to January 1977, the lagged spot rate was a better forecaster than the forward rate for five of seven currencies (relative to the US dollar). Levich [17] found that for the period 1967–1975, the lagged spot rate did better than the one-month forward rate for seven of nine currencies. Most recently, Longworth [18] in his studies of efficiency of United States-Canadian exchange market, also found that lagged spot rate yields lower root mean square errors of forecasts than that of forward rate in the prediction of future spot rate. Based on this information, I contend that using lagged values of spot rate in conjunction with a final prediction error criterion will generate an optimal predicted value of the future spot rate.

14. $\sum_{j=1}^{3} b_s(j) = 0.934$ ($= 0.943$ if including the current innovations in the estimation) for Germany; and $\sum_{j=1}^{5} b_s(j) = 0.912$ ($=0.967$ if including the current innovations in estimation) for France.

15. In addition to news, it should be noted that a nonconstant risk premium may also play a role in explaining the exchange rate behavior. This point has been explored in Hansen and Hodrick [15].

16. The lagged innovations of real income and interest rate were excluded from the exchange rate equation for the United Kingdom, and innovation of interest rate was eliminated for Italy, simply because the inclusion of these variables would not produce minimum FPE in the exchange rate equations.

17. See Chiang [7] for detail.

18. I also found that the hypothesis that current innovations have no effect on current spot rate cannot be rejected for the United Kingdom and Germany. But, the hypothesis is rejected for Italy and France. The rejection of the null hypothesis suggests that the current unexpected changes in spot rate do respond contemporaneously to the unexpected changes in current interest rate differential although this result is not inconsistent with the rational expectations of monetary models.

19. The possible announced lag of information may blur our results. For instance, the money supply figure in the United Kingdom is available only if there is one month lag; the efficient market then is consistent with the significance of $b_m(1)$. However, if both $b_m(1)$ and $b_m(2)$ are significant in a consecutive manner, then there are adjustment lags in the foreign exchange market.

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