Money

1982

SOME EVIDENCE IN FAVOR OF A MONETARY MODEL OF EXCHANGE RATE DETERMINATION

by

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Working Paper Series
No. 201

AUGUST 1982

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We thank Anil Kashyap and Marlene Cerci for useful research assistance.

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I. INTRODUCTION

Despite the apparent successes of early tests of monetary, rational expectations models of exchange rate behavior (see Frankel, (1979)), their reputations have been recently tarnished as more data and alternative econometric techniques have become available (see Driskill and Sheffrin (1981), and Meese and Rogoff (1981)). Professional response to this event has taken an interesting form: some early proponents of the usefulness of rational expectations have now eschewed them, instead clinging to other features of the monetary models (see Frankel (1981)).

In this paper, we take another tack, and maintain the rational expectations hypothesis while amending the monetary model to incorporate imperfect capital substitutability and current-account effects. We then make use of implications of the rational expectations hypothesis to test the model. Our primary finding is that this model is generally consistent with the data, providing some evidence in favor of the rational expectations hypothesis.

Our theoretical model is part of a line of work which emphasizes the interplay between risk-aversion, rational speculators and current-account flow-market phenomena. Our model thus belongs to the generic class of inventory-speculation models beginning with Muth (1961) and extending, in the foreign exchange literature, through Black (1972), and Driskill and McCafferty (1981). To keep the analysis tractable, we have been forced to take a partial equilibrium approach, whereby money, real income, and price levels are treated as exogenous to the foreign exchange market. Ideally, we would want to develop a general equilibrium model accounting for feedback effects from the exchange rate to income and price levels but, at the moment, this is beyond our grasp. Even with our partial equilibrium approach, though, we are left with an ambitious econometric project. To mitigate the effects of our partial-equilibrium simplification, we specifically chose the Swiss franc/U.S. dollar exchange rate for our empirical work: it seems quite plausible that the Swiss/U.S. exchange rate has small effects on other Swiss/U.S. macrovariables.[1]

Our choice of the Swiss/U.S. exchange rate highlights additional methodological considerations. We argued elsewhere (Driskill and Sheffrin (1981), pg. 1072, and Driskill (1981)) that most other commonly used bilateral exchange rates offer special problems that make it inappropriate to confront them with simple empirical monetary models. In brief, these problems arise from either managed floating vis-a-vis the dollar, or from the explicit linking of currency values as in the "Snake" arrangements. Our desire is to find an appropriate testing ground to explore whether our theoretical notions have some empirical validity. In this manner, we hope to identify those components of a monetary model which can be used as building blocks in models more appropriate for other exchange rate investigations. The Swiss franc, which is not part of any European currency area and by and large floats freely vis-a-vis the dollar, seems suitable.

Our empirical work has intellectual linkages in two directions. In the exchange-rate literature, one link is to Driskill (1981), who estimated an exchange-rate reduced-form equation for the Swiss franc/U.S. dollar rate.

His study, though, was not based on a rational expectations model and provided no structural estimates. Another link is to McNelis and Condor (1982), who also investigate the Swiss/U.S. exchange rate, but again do not appeal to rational expectations or uncover structural parameters. Their emphasis is on the empirical gains achieved by estimating time-varying parameters.

The other linkage from our work is to a growing literature on testing and estimating rational expectations models by making use of overidentifying restrictions imposed by the rational expectations assumption. The theoretical underpinnings of this work are associated with Wallis (1981) and Hansen and Sargent (1980). Implementation of this approach includes work by Blanchard (1981), Driskill and Sheffrin (1981), Eckstein (1981), Goodwin and Sheffrin (1982), and Sargent (1978). The Blanchard, Eckstein and Sargent papers are especially relevant, in that all estimate models with an inherent speculative structure broadly analogous to that of our own.

II. THE MODEL

Our model may be termed "monetary" in as much as relative money supplies play a prominent role in exchange-rate determination. The feature which distinguishes it from most other monetary models are its assumptions about stock/flow interactions under conditions of less-than-perfect international capital substitutability. In addition, we focus primarily on the foreign exchange and money markets, assuming prices, real incomes, and money supplies are exogenous to the exchange rate.

The basic building blocks of the model are a money market equilibrium condition, a foreign exchange market equilibrium condition, and a specification of the stochastic processes governing the behavior of the exogenous forcing variables, in our case, relative money supplies, income levels, and price levels. Most variables will be expressed as logarithms of <u>relative</u> variables, that is, as the log of the ratio of U.S. to Swiss variables.[2]

A. <u>Money market equilibrium</u>

Money demand takes the well-known form of:

$$m_t - p_t = -\lambda^{-1} r_t + \hat{\Pi} y_t \tag{1}$$

where m, p, and y are logs of the ratio of domestic to foreign money supplies, price levels, and real income levels, respectively. The interest rate differential is r_t, which means that λ^{-1} is the interest semi-elasticity of the demand for money. The money demand income elasticity is $\hat{\Pi}$. Assuming demand equals the exogenous supply, equation (1) can be rewritten:

$$r_t = \lambda m_t + \lambda p_t + \Pi y_t \tag{2}$$

where $\Pi = \lambda\hat{\Pi}$.

B. Foreign exchange market equilibrium

The major components of the foreign exchange building block are specifications of trade balance behavior, capital flow behavior, and a market equilibrium condition.

The trade balance, measured in foreign currency units, is expressed as follows:

$$T_t = \alpha(e_t - p_t) - \Psi y_t \qquad (3)$$

where $\alpha > 0$, $\Psi > 0$. This equation simply says that the trade balance depends on relative prices and income. Assuming $\alpha > 0$ amounts to an assumption that the Marshall-Lerner condition is satisfied.

The net stock demand for foreign assets is assumed linearly dependent on the expected relative rate of return:

$$F_t = \eta\, [E_t e_{t+1} - e_t - r_t] \quad , \quad \eta > 0 \qquad (4)$$

This, of course, is a very simple specification of asset demand, but captures, we think, the critical feature of speculative behavior in international capital markets. Perfect capital substitutability would correspond to $\eta \to \infty$. $E_t(\cdot)$ is the expectations operator, conditional on information available at time t-1.

Market equilibrium is described by the equality of net capital exports with the trade balance surplus, T_t, plus autonomous flows, $\overline{A}$:

$$\Delta F_t = T_t + \overline{A} \tag{5}$$

$\overline{A}$ is assumed constant, and for expositional ease will be set equal to zero.

C. Solution of the model

By substitution of (2), (3), and (4) into the equilibrium condition (5), we can write:

$$\eta E_t e_{t+1} + -\alpha\, e_t - \eta\, E_{t-1}\, e_t + \eta e_{t-1} =$$

$$(-\alpha + \eta\lambda)P_t - \eta\lambda P_{t-1} + (\eta\Pi - \Psi)y_t - \eta\Pi y_{t-1} - \eta\lambda m_t + \eta\lambda m_{t-1} \tag{6}$$

By taking the projection of both sides of (6) on information available at t-1 and rearranging, we find:

$$(1-X^{-1}B)(1-XB)E_{t-1}\, e_t = (\lambda - \frac{\alpha}{\eta})E_{t-1}P_{t-2} + \frac{(\eta\Pi-\Psi)}{\eta} E_{t-1}\, y_{t-1}$$

$$-\Pi E_{t-1}\, y_{t-2} - \lambda E_{t-1}M_{t-1} + \lambda E_{t-1}M_{t-2} \tag{7}$$

where $X + X^{-1} = \frac{\alpha}{\eta} + 2$ and B is an operator such that:

$$B\; E_{t-1}\, e_t = E_{t-1}\, e_{t-1} \tag{8a}$$

$$B^{-1}\, E_{t-1}\, e_t = E_{t-1}\, e_{t+1} \tag{8b}$$

Operating on (7) with the forward inverse of $(1-X^{-1}B) \equiv \frac{-XB^{-1}}{1-XB^{-1}}$, we have:

$$(1-XB)E_{t-1}e_t = -X\ \{(\frac{-\alpha}{\eta} + \lambda)\sum_{i=0}^{\infty}X^i\ E_{t-1}\ p_{t+i} - \lambda \sum_{i=0}^{\infty}X^i E_{t-1}\ p_{t+i-1}$$

$$+ (\frac{\Pi=\Psi}{\eta}) \sum_{i=0}^{\infty}X^i E_{t-1}\ y_{t+i} - \Pi \sum_{i=0}^{\infty} X^i E_{t-1}\ y_{t+i-1}$$

$$-\lambda \sum_{i=0}^{\infty} X^i E_{t-i}\ M_{t+i} + \lambda \sum_{i=0}^{\infty} X^i E_{t-1} M_{t+i-1}\ \} \qquad (9)$$

or, equivalently,

$$E_{t-1}e_t = Xe_{t-1} - X\{\cdot\} \qquad (10)$$

where $\{\cdot\}$ is the bracketed term on the right-hand-side of (9). Equation (10) gives us the expression for the conditional expectation of the exchange rate in terms of the discounted present value of expected future values of the forcing variables. By updating (10) one time period, we also get a similar equation for $E_t e_{t+1}$. Knowing $E_{t-1}e_t$ and $E_t e_{t+1}$, we can substitute their values back into (6), the structural equation, to yield:

$$e_t = \frac{\eta(1-x)}{\eta(1-x)+\alpha}\ e_{t-1}\ \frac{-(\eta\lambda-\alpha)}{\eta(1-x)+\alpha}\ p_t + \frac{\eta\lambda}{\eta(1-x)+\alpha}\ p_{t-1}\ \frac{-(\Pi\eta-\Psi)}{\eta(1-x)+\alpha}\ y_t$$

$$\frac{+\Pi\eta}{\eta(1-x)+\alpha}\ y_{t-1}\ \frac{+\eta\lambda}{\eta(1-x)+\alpha}\ m_t\ \frac{-\eta\lambda}{\eta(1-x)+\alpha}\ m_{t-1}$$

$$\frac{+\eta x}{\eta(1-x)+\alpha} \{(\frac{-\alpha}{\eta} + \eta)\sum_{i=o}^{\infty} x^i E_t P_{t+i+1} - \eta\sum_{i=0}^{\infty} E_t P_{t+i} + (\Pi - \frac{\Psi}{\eta})\sum_{i=0}^{\infty} x^i E_t y_{t+i+1}$$

$$-\Pi\sum_{i=0}^{\infty} x^i E_t y_{t+i} - \lambda\sum_{i=0}^{\infty} x^i E_t m_{t+i+1} + \lambda \sum_{i=0}^{\infty} x^i E_t m_{t+i} \}$$

$$\frac{-\eta x}{\eta(1-x)+\alpha} \{(-\frac{\alpha}{\eta} + \lambda)\sum_{i=0}^{\infty} x^i \; E_{t-1} P_{t+1} - \lambda \sum_{i=0}^{\infty} E_{t-1} \; P_{t+i-1} + (\Pi - \frac{\Psi}{\eta})\sum_{i=0}^{\infty} E_{t-1} y_{t+i}$$

$$-\Pi\sum_{i=0}^{\infty} x^i E_{t-1} \; y_{t+i-1} - \lambda\sum_{i=0}^{\infty} x^i E_{t-1} \; m_{t+i} + \lambda \sum_{i=0}^{\infty} x^i E_{t-1} \; m_{t+i-1} \} \quad (11)$$

One can verify that:

$$\frac{\eta(1-x)}{\eta(1-x)+\alpha} = x \quad (12)$$

hence, the coefficient on e_{t-1} in (11) is just x. Furthermore, from (12), we see that:

$$\{\eta(1-x)+\alpha\} = \frac{\eta(1-x)}{x} \quad (13)$$

and that

$$\frac{\alpha}{\eta} = \frac{(1-x)^2}{x} \quad (14)$$

III. EMPIRICAL IMPLEMENTATION

Equation (11) contains unobservable sums of future expectations and cannot be estimated directly. In order to estimate the model, it is necessary to express these unobservable sums in terms of observable variables. The conventional procedure in the rational expectations literature is to model the forcing variables (m_t, y_t, P_t) as time-series processes and assume agents use these stochastic processes for forecasting. This leads to testable cross-equation restrictions between the exchange rate equation and the equations for the stochastic processes of the forcing variables.

Ideally, we would have preferred to work with a full vector time series representation, but the restrictions that arose in the econometric implementation were extremely complicated and exceeded the capacity of our computer programs. We were led, therefore, to modeling the forcing variables as univariate autoregressive processes as in Eckstein (1981). Some initial experimentation revealed that both m_t and P_t could be described by first-order processes (with constants) while y_t followed a second-order process with a constant. While these are simple models, previous work (Frankel (1979), Driskill and Sheffrin (1981)) using logs of <u>relative</u> money supplies, income, and prices has had success with parsimonious representations.

It remains to derive observable expressions for the discounted sums of future expectations. Hansen and Sargent (1980) prove that if a variable W_t follows the univariate stochastic process:

$$\alpha(L)W_t = V_t \tag{15}$$

<u>where</u>: $\alpha(L) = 1 - \alpha_1 L - \alpha_2 L \ldots - \alpha_q L^q$

L lag operator, V_t white noise

then

$$\sum_{i=0}^{\infty} X^i E_t W_{t+i} = \alpha(X)^{-1} \left[1 + \sum_{j=1}^{q-1} \left(\sum_{k=j+1}^{q} X^{k-j} \alpha_k \right) L^j \right] W_t \tag{16}$$

Applying these formulas to equation (11), using equations (13) and (14) and taking into account the dating of the sums, yields the observable system of equations that can be estimated and appears in Table 1.

A few observations on the exchange rate equation are relevant. First, the sum of the coefficients on e_{t-1}, P_t, P_{t-1}, m_t and m_{t-1} is one; this reflects the long-run homogeneity of prices and exchange rates in the model with respect to the money supply. In other words, our model is consistent with long-run purchasing power parity. Second, the coefficients on m_t and m_{t-1} are of equal magnitude but opposite sign, the one on m_t being positive. Furthermore, the m_t coefficient ($\frac{\lambda x}{1-b_1 x}$) may be greater or less than one; if greater, the model exhibits overshooting a la' Dornbusch (1976). Overshooting in our model, though, is an empirical question, depending on the interaction of λ, the inverse of money demand interest rate semi-elasticity, and x, which is itself a decreasing function of $\frac{\alpha}{\eta}$.[3] Hence, low values of the money demand interest rate semi-elasticity, and low values of $\frac{\alpha}{\eta}$ tend to make overshooting more likely. That is, in addition to interest elasticities, overshooting depends in part on the relative responsiveness of trade flows to relative prices (α) vis-a-vis the responsiveness of stock demands for foreign assets to relative yields (η).

The error terms in the equations are allowed to be contemporaneously correlated but not correlated with past values. This requires that the original error term in the interest rate equation be a random walk. Our estimation method also requires that the exchange rate fail to Granger-cause P_t, m_t and y_t. Unfortunately, our limited sample size (32 observations) precluded meaningful tests of this sort.[4]

We can subject the model to four tests. First, we can check if the unrestricted parameter estimates in the exchange rate equation have the correct sign. The second test is to check if further lagged values of the forcing variables have explanatory power in the equation rate equation. If the model is correct, they should not help to explain exchange rate movements. The third test involves estimating the full system imposing all the cross-equation constraints and checking to see if the estimated coefficients have the anticipated signs and magnitudes. Finally, the last test is a formal likelihood test of the restrictions imposed jointly by the specification of the model and the rational expectations hypothesis.

Table II presents the results of an unrestricted estimation of equations using data from the NBER data bank. These are several predictions concerning the unrestricted equation rate equation. The coefficient on the lagged exchange rate should be between zero and one; the coefficient on m_t should be positive and the coefficient on m_{t-1} should be negative and of equal size. The predictions are generally fulfilled. The coefficient on x is between zero and 1 (.67) while the coefficients on m_t and m_{t-1} have the correct sign and are similar in absolute value (1.26 and -1.85 respectively).

To perform the second test, we added additional lagged values of the forcing variables to the exchange rate equation. The theory suggests that they should not be statistically significant because they do not help to predict the evolution of the forcing variables. This is indeed what we find. Adding y_{t-2}, P_{t-2}, and m_{t-2} did not improve the fit of the equation. The "F" statistic had a value of .2829 whereas the critical value at the 5% level is 3.01.

Because we do not have data on the trade balance or capital flows, we would not expect to be able to estimate all the parameters of the model. Surprisingly, data on only income, prices, money and exchange rates can give estimates of some of the key parameters in the model. In particular, we can estimate:

(a) x, which from equation (14) implies a value for α/η -- This term is the ratio of the terms of trade effect on the trade balance to the parameter measuring speculation. Stability of the model requires $\alpha > 0$. Imperfect capital mobility will lead to a finite and positive value for η. Thus, this term should be positive.

(b) $\frac{\Psi}{\eta}$ -- This term is the ratio of the income sensitivity of the trade balance to the speculative parameter. It should also be positive, but could be small if the trade balance is not that sensitive to changes in income.

(c) Π and λ -- These are the coefficients on income and both money and prices in the interest rate equation. Because of the way the variables are defined, λ is the inverse of the semi-elasticity of money demand.

Table II presents the model and the parameter estimates. The entire system was estimated by full-information maximum likelihood. Different initial conditions led to the same parameter estimates that appear in Table II.

Most of the parameter estimates are quite reasonable. A value of "X" of .67 implies a value of .17 for $^{\alpha}/_{\eta}$. This coefficient has the correct sign and implies that the speculative effects are about six times as strong as the terms of trade effects. The parameter Π had the correct sign but was not estimated precisely. The inverse of the semi-elasticity had a value of 3.15 which is roughly consistent with an interest elasticity of .04 and interest rates of twelve percent. Considering the difficulty in pinning down estimates of interest elasticities of money demand (Cooley and Leroy (1981)), this is a low but plausible estimate.

The one term that did not have the anticipated sign was $^{\Psi}/_{\eta}$ but it was not statistically significant. This suggests that income effects were not important for the trade balance.

Finally, a formal likelihood ratio test indicates that the restrictions could not be rejected. Twice the difference of the log likelihoods between the constrained and unconstrained versions of the model was .52 whereas the critical value of the chi-squared distribution at the five percent level with four degrees of freedom is 9.48. The model clearly passes our fourth test.

A calculation of the coefficient on m_t from the estimates in Table I yields an overshooting estimate of 5.8. This high number, in large part, results from a low estimated interest elasticity. The unconstrained estimate also exhibits overshooting but is smaller (1.26).

IV. CONCLUSIONS AND SUGGESTIONS FOR FUTURE RESEARCH

Our findings suggest that a monetary, rational-expectations model of exchange-rate determination is broadly consistent with recent Swiss/U.S. data. One interpretation of this result is that the post-mortems being conducted on exchange-rate models of the '70's are, if not premature, at least restricted in applicability to the starkly simple models incorporating perfect capital substitutability and mobility. In addition, our failure to reject the joint hypothesis of our structural model and the RE assumption provides some evidence that the empirical demise of these earlier models is not due so much to the assumption of rational expectations as to their particular array of simplifying assumptions.

Of course, our results are, at the moment, more suggestive than definitive. Fruitful extensions may be found in a number of directions. First, the relaxation of the partial-equilibrium assumptions of the model should prove useful. Second, extensions incorporating aspects of managed floating should create a model with empirical implications for exchange rates other than the Swiss-U.S. rate.

In closing, it might be useful to recount the most salient empirical results of our paper. First, the overidentifying restrictions imposed on the model by the rational expectations assumption are not rejected. Second, we find that the ratio of the measure of capital substitutability to goods (trade-balance) substitutability is roughly 6 to 1 - high, but not infinite. Third, we find evidence of Dornbuschian overshooting: an unanticipated increase in relative money supplies leads to a more-than-proportional change in the current exchange rate.

TABLE I

CONSTRAINED MODEL AND PARAMETER ESTIMATES

1. $$e_t = \text{constant} + xe_{t-1} + \frac{x}{1-a_1x}\{-\lambda + \frac{(1-x)}{x}\}\, P_t + \frac{x}{1-a_1x}\{\lambda - a_1(1-x)\}\, P_{t-1}$$

$$+ \frac{\lambda x}{1-b_1x} m_t - \frac{\lambda x}{1-b_1x} m_{t-1} + \frac{x}{1-x}\left\{\frac{\Pi(1-x) - \Psi/\eta}{1-c_1x-c_2x^2}\right\} y_t$$

$$+ \frac{x}{1-x}\left\{\frac{-\Pi(1-x)(1-c_2x) + \frac{\Psi}{\eta}\, x\,(c_1 - c_2\,(1-x))}{1-c_1x-c_2x^2}\right\} y_{t-1}$$

$$+ \frac{x^2}{1-x}\left\{\frac{-\Pi\, c_2\,(1-x) + \frac{\Psi}{\eta}\, c_2}{1-c_1x-c_2x^2}\right\} y_{t-2}$$

2. $P_t = \text{constant} + a_1\, P_{t-1}$

3. $m_t = \text{constant} + b_1\, m_{t-1}$

4. $y_t = \text{constant} + c_1\, y_{t-1} + c_2\, y_{t-2}$

Log Likelihood 281.409
Period 1973:2 - 1981:3

	Parameter	Coefficient	Std Error
	x	.66	.14
	λ	3.15	1.97
	Π	.078	.45
	Ψ/η	-.55	.46
	a_1	1.04	.01
	b_1	.97	.04
	c_1	.53	.16
	c_2	.34	.15
Constants in	exchange rate	-.34	.14
	prices	.08	.002
	income	.015	.008
	money	.054	.096

TABLE II

UNCONSTRAINED ESTIMATES

1. $$e_t = \underset{(1.72)}{.88}\; e + \underset{(.14)}{.67}\; e_{t-1} + \underset{(.72)}{1.26}\; m_t - \underset{(.85)}{1.85}\; m_{t-1}$$

$$+ \underset{(1.31)}{4.82}\; P_t - \underset{(1.29)}{4.79}\; P_{t-1} + \underset{(.34)}{.96}\; y_t + \underset{(.32)}{.068}\; y_{t-1}$$

$$+ \underset{(.31)}{.006}\; y_{t-2}$$

2. $$P_t = \underset{(.002)}{.008} + \underset{(.014)}{1.04}\; P_{t-1}$$

3. $$m_t = \underset{(.11)}{.04} + \underset{(.05)}{.98}\; m_{t-1}$$

4. $$y_t = \underset{(.008)}{.015} + \underset{(.17)}{.54}\; y_{t-1} + \underset{(.16)}{.33}\; y_{t-2}$$

Log Likelihood = 281.635
Period: 1973:2 - 1981:3

FOOTNOTES

[1]For an attempt to empirically uncover the general-equilibrium linkages in Frankel's (1979) model, see Driskill and Sheffrin (1981).

[2]We assume the structural parameters are identical across countries.

[3]Our equation for x is: $x + \frac{1}{x} - 2 = \frac{\alpha}{\eta}$

Straightforward differentiation shows that $\frac{dx}{d(\frac{\alpha}{\eta})} = \frac{x^2-1}{x^2} < 0$.

[4]Hansen and Sargent (1982) have recently proposed estimators which can be used in the absence of Granger-causality.

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