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ACTIVIST MONETARY POLICY AND EXCHANGE RATE OVERSHOOTING: THE DEUTSCHE MARK/DOLLAR RATE

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ABSTRACT

After a decade of generalized floating, it is clear that bilateral exchange rates exhibit more variability than the economic aggregates; relative prices, incomes, and money supplies, that generally comprise the fundamentals of theories of exchange rate determination. Dornbush's overshooting hypothesis is the best known explanation of this phenomenon. This paper shows that accommodative monetary policy (with respect to prices) has the potential to cause the economy to switch from exchange rate overshooting to undershooting. Using constrained maximum likelihood methods, the model is estimated for Germany and the United States. The results provide strong evidence in support of the overshooting hypothesis for the Deutsche Mark/Dollar exchange rate.

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I. Introduction

It is by now well established that bilateral exchange rates exhibit more variability than the economic aggregates—relative prices, incomes, and money supplies--that generally form the fundamentals of theories of exchange rate determination.[1] In particular, it is clear that real exchange rate variability, or deviations from purchasing power parity, characterized the 1970's. Real exchange rate variability provides an important channel through which one country's economic policies affect other countries. Flexible exchange rates no longer seem to offer the promise of macroeconomic independence that they once did.

The overshooting hypothesis, as exemplified by Dornbusch (1976), was an attempt to explain this pattern of variability. Using a model with perfect capital mobility, fixed output, and slow price adjustment, he showed how an increase in the (exogenous) money supply would cause the exchange rate first to depreciate beyond its long run equilibrium value, and then to appreciate back to the steady state.[2] Frankel (1979) estimated a two-country model with many similarities to that of Dornbusch, and found evidence supporting overshooting for the Deutsche mark/dollar rate. Subsequently, Frenkel and Rodriguez (1982) have argued that overshooting is not an intrinsic characteristic of the foreign exchange market. Allowing for imperfect capital mobility in the Dornbusch model, they raise the possibility of undershooting, where the initial depreciation, below its long run equilibrium value, is followed by further depreciation until the steady state is attained.[3]

The overshooting results described above are derived under the assumption that the money supply is exogenous, an assumption that is at odds with the available empirical evidence. For example, Mussa (1981b) argues that the behavior of exchange rates has influenced the conduct of monetary policy in

the United States, United Kingdom, and Germany. Taylor (1982) provides econometric evidence that the money supply accommodates price movements in a number of countries.

This paper considers the effect of activist monetary policy on exchange rate overshooting.[4] The model is a two-country, variable output version of Dornbusch's model with the money supply responsive to price and/or exchange rate movements. The main theoretical result is that accommodative monetary policy (with respect to prices) can cause the economy to switch from exchange rate overshooting to undershooting. This can occur even with fixed output, slow price adjustment, and perfect capital mobility.

Using quarterly data beginning in 1973, the model is estimated for Germany and the United States. The policy and structural parameters are jointly estimated in accordance with Lucas' (1976) critique of econometric policy evaluation. Constrained maximum likelihood techniques, which impose the cross equation restrictions derived from the structural equations and assumption of rational expectations, are used for the estimation. Two measures of the price index are used, the Wholesale Price Index (WPI) and the Gross National Product Deflator. The results provide strong evidence in support of the overshooting hypothesis for the Deutsche Mark/Dollar exchange rate. For the WPI, the exchange rate overshoots because neither German nor American monetary policy is particularly responsive to prices. For the GNP deflator, the exchange rate overshoots because accommodative American monetary policy is counteracted by offsetting German monetary policy. While the combination of policies is accommodative, it is not sufficiently accommodative to produce undershooting. Variable output is unimportant.

The results of this paper are relevant to an analysis of recent developments in American monetary policy. They predict that a less accommodative

American monetary policy will increase the amount of overshooting of the Deutsche mark/dollar Rate. While the sample period is too short to formally test for a change in the money supply rule with the advent of the Reagan administration, it is possible to conjecture that one of the reasons for the high volatility of the Deutsche mark/dollar rate beginning in 1981 may be a less accommodative monetary policy on the part of the United States.[5]

The paper is organized as follows. The model is presented in Section II. The theoretical results concerning overshooting and undershooting are derived in Section III and the model is estimated in Section IV. Conclusions and extensions are presented in Section V.

II. The Model

The model is a two-country, variable output version of Dornbusch (1976), which differs from the work of Dornbusch and Frankel in the specification of the price adjustment equation and in that the domestic and foreign money supplies are determined endogenously. In order to focus attention on the relationship between monetary activism and exchange rate overshooting, to provide comparability between this and previous work, and to remain tractable, the model contains a number of simplifying assumptions.[6] It consists of the following equations.[7]

$$(1) \qquad (m_t - m_t^*) - (p_t - p_t^*) = (y_t - y_t^*) - a_1(i_t - i_t^*) + \varepsilon_{1t}$$

$$(2) \qquad y_t = \bar{y} + a_2(e_t + p_t^* - p_t) + \varepsilon_{2t}$$

$$(3) \qquad y_t^* = \bar{y}^* - a_3(e_t + p_t^* - p_t) + \varepsilon_{3t}$$

$$(4) \qquad (p_{t+1} - p_{t+1}^*) - (p_t - p_t^*) = a_4(\hat{e}_{t+1} - e_t) + a_5(e_t + p_t^* - p_t) + \varepsilon_{4t}$$

$$(5) \qquad m_t = \bar{m} + a_6\tilde{e}_t + a_7(\tilde{p}_t - \tilde{p}_t^*) + \varepsilon_{4t}$$

(6) $$m_t^* = \bar{m}^* - a_8\tilde{e}_t - a_9(\tilde{p}_t - \tilde{p}_t^*) + \varepsilon_{5t}$$

(7) $$i_t = i_t^* + (\hat{e}_{t+1} - e_t)$$

where m is the logarithm of the domestic money supply,

p is the logarithm of the domestic price level,

y is the logarithm of domestic real income,

e is the logarithm of the exchange rate (domestic currency price of foreign exchange),

i is the domestic nominal interest rate,

* associated with a variable indicates that it refers to the foreign country,

~ over a variable indicates deviation from the steady state level,

$\bar{y}$ is the steady state level of output,

$\bar{m}$ is the exogenous component of the money supply,

$\hat{e}_{t+1}$ is the expectation of the exchange rate for period t+1, conditional on information available in period t.

The ε's are random disturbances, which may be serially correlated.

Asset market equilibrium is described in Equation (1). Supply of and demand for real balances in each country are equated in equilibrium, and the demand for money depends positively on income and negatively on the interest rate.

(1a) $$m_t - p_t = y_t - a_1 i_t + \varepsilon_{11t}$$

(1b) $$m_t^* - p_t^* = y_t^* - a_1 i_t^* + \varepsilon_{12t}$$

Setting the income elasticity of the demand for money equal to unity does not affect the theoretical results. Equating the interest rate semi-elasticities

of the two countries is done for tractability.[8] Equation (1) is obtained by subtracting (1b) from (1a) and setting $\varepsilon_{1t} = \varepsilon_{11t} - \varepsilon_{12t}$.[9]

The deviation of output from its long run equilibrium (natural rate) level in each country depends on the relative price of domestic and foreign goods in equations (2) and (3). If the relative price of foreign goods is high ($e_t + p_t^* > p_t$) domestic output is above and foreign output is below their respective long run values.[10,11] It is assumed that long run purchasing power parity holds ($\bar{e} + \bar{p}^* = \bar{p}$).

The behavior of prices described by equation (4) encompasses two influential formulations. In Dornbusch (1976), the rate of inflation depends on relative prices, which in turn represents excess demand in the goods market. In our notation,

$$(4a) \qquad p_{t+1} - p_t = b_1(e_t + p_t^* - p_t) + \varepsilon_{41t},$$

$$(4b) \qquad p_{t+1}^* - p_t^* = -b_2(e_t + p_t^* - p_t) + \varepsilon_{42t},$$

which, by subtraction and setting $a_5 = b_1 + b_2$ and $\varepsilon_{4t} = \varepsilon_{41t} - \varepsilon_{42t}$, becomes equation (4) with $a_4 = 0$. Mussa (1981a, 1982) argues that a superior formulation is to specify the rate of inflation as equal to the expected rate of change of the equilibrium price level, plus some proportion (< 1) of the difference between the equilibrium and actual price levels.[12] With long run purchasing power parity and, as in Dornbusch (1976), pre-determined prices, Mussa's specification is,[13]

$$(4c) \qquad p_{t+1} - p_t = (\hat{e}_{t+1} + p_{t+1}^*) - (e_t + p_t^*) + a_5(e_t + p_t^* - p_t) + \varepsilon_{4t},$$

which can be manipulated to become equation (4) with $a_4 = 1$. Dornbusch's and Mussa's equations produce quite similar theoretical results with regard to

over and undershooting. Equation (4) spans the two formulations, and allows us to distinguish between them empirically.

The money supply for each country depends on both the exchange rate and on the difference between domestic and foreign prices.[14] The monetary authorities are assumed to use the information conveyed by the contemporaneous exchange rate and (pre-determined) prices.[15] From the perspective of the domestic country, if the exchange rate depreciates (increases), the money supply is accommodative if $a_6 > 0$, offsetting if $a_6 < 0$. For example, an offsetting rule would decrease the money supply in response to a depreciation in order to cause the exchange rate to appreciate. From the foreign country's perspective, since a depreciation is a decrease in e, an accommodative rule consists of $a_8 > 0$, an offsetting rule of $a_8 < 0$.

The terminology with respect to price movements is similar. If the ratio of domestic to foreign prices increases, policy is accommodative if a_7 and/or $a_9 > 0$, offsetting if a_7 and/or $a_9 < 0$. The money supply is constrained to respond to the price ratio, rather than to the levels separately, because, in the reduced form of the model, prices appear only in ratio form. This can cause some semantic difficulties in considering foreign price movements. In some of the discussions of supply shocks, an increase in the foreign price level (or price of the imported good) would cause the domestic price index to increase. In that context, accommodative monetary policy implies that the domestic money supply increases when the foreign price level increases. In this paper, accommodative monetary policy implies that the domestic money supply decreases when the foreign price level increases. While allowing the money supplies to respond separately to domestic and foreign price levels would be preferable to the scheme adopted in this paper, it would make the model analytically intractable.[16] The money supply could have been postulated

to respond directly to output movements without affecting the theoretical results. This would constrain $a_6 = -a_7$. In this sense, monetary policy that offsets exchange rate movements and accommodates price movements can be interpreted as attempting to stabilize output. In addition, the money supply rule for each country includes an exogenous term and a stochastic disturbance term.

Equation (7) is the representation of uncovered interest rate parity: the domestic interest rate equals the foreign interest rate plus the expected rate of depreciation. While the empirical evidence concerning this proposition has been mixed, it is at worst a fairly good approximation for the Deutsche mark/dollar rate.[17]

III. Overshooting and Undershooting

In this section, it is shown how monetary policy that accommodates price movements can cause exchange rate undershooting in a situation that would otherwise be characterised by overshooting. In Dornbusch (1976), undershooting can only occur if the elasticity of demand for output with respect to relative prices is greater than one, while in Frenkel and Rodriguez (1982), imperfect capital mobility is necessary for undershooting. This paper shows that, even when output is fixed and capital perfectly mobile, sufficiently accommodative monetary policy can cause the exchange rate to undershoot.

The clearest way to derive and illustrate these results is through a deterministic specification with perfect foresight expectations. (The econometric work below will, of course, be presented in a stochastic, rational expectation setting.) Assuming that expectations are perfect foresight, setting the disturbances equal to zero, substituting equations (2), (3), (5), (6) and (7) into (1), and taking deviations from steady state equilibrium, we

obtain:

$$(8) \qquad \begin{vmatrix} De_t \\ Dq_t \end{vmatrix} = \begin{vmatrix} \delta_1 & \delta_2 \\ \delta_3 & \delta_4 \end{vmatrix} \begin{vmatrix} e_t - \bar{e} \\ q_t - \bar{q} \end{vmatrix}$$

where $q_t \equiv p_t - p_t^*$ (the logarithm of the ratio of domestic to foreign prices)

D is the forward difference operator, i.e., $Dx_t = x_{t+1} - x_t$ for $x = (e, q)$.

$$\delta_1 = \frac{a_2 + a_3 - a_6 - a_8}{a_1} \qquad \delta_2 = \frac{1 - a_2 - a_3 - a_5 - a_7}{a_1}$$

$$\delta_3 = \delta_1 a_4 + a_5 \qquad \delta_4 = \delta_2 a_4 - a_5 .$$

Several configurations of the model can be produced by considering different money supply rules. We assume that the money supply[18] either offsets or is not too accommodative of exchange rate movements, so that $\delta_1 > 0$. (If $\delta_1 < 0$, there can be either overshooting or a non-unique solution, but not undershooting.) If monetary policy acts to stabilize output, a_6 and $a_8 < 0$, $\delta_1 > 0$ and the possibility of non-uniqueness does not arise.[19] The behavior of the model is now determined by the elasticity of domestic and foreign demand with respect to relative prices $(a_2 + a_3)$, and the degree of accommodation of domestic (a_7) and foreign (a_9) monetary policy to price movements. The case where output is not too variable and/or policy is not too accommodative, so that $\delta_2 > 0$, is illustrated in Figure 1.[20] In order to facilitate comparison with previous work, we depict Dornbusch's formulation $(a_4 = 0)$ where the slope of the $Dq_t = 0$ curve is equal to unity. This is solely for the purpose of illustration; the results are not affected.

With both δ_1 and $\delta_2 > 0$, the slope of the $De_t = 0$ curve is negative. Consider an unanticipated, permanent increase in the exogenous component of the domestic money supply,[21] starting from a position of long run equilibrium, which shifts the $De_t = 0$ schedule to the right.[22] The motion of the variable

is indicated by the direction of the arrows, which are drawn in reference to the schedules once the disturbance occurs. The unique perfect foresight equlibrium path, the saddle path, is downward sloping. The initial equilibrium is at E. At the time of the disturbance, the price level, being pre-determined, is fixed. The exchange rate must jump (depreciate) to E^1 so as to be on the new saddle path, and then appreciate along the saddle path towards the new long run equilibrium E^2. This, of course, is the process of overshooting described by Dornbusch.

Now consider the case where there is either enough monetary accommodation to price movements and/or the elasticity of demand with respect to relative prices is high enough so that $\delta_2 < 0$. As illustrated in Figure 2, $\delta_1 > 0$ and $\delta_2 < 0$ implies that the slope of the $De_t = 0$ curve is positive.[23] Since the slope of the saddle path is now positive, there is exchange rate undershooting. Following the increase in $\bar{m}$, the exchange rate depreciates to E^1. It then continues to depreciate until the long run equilibrium is attained at E^2.

It is illustrative to compare these results with those of Dornbusch. If both countries' money supplies are exogenous, i.e., if there is no response to either the exchange rate or the price ratio, the model reduces to Dornbusch's flexible output case. The necessary and sufficient condition for overshooting is that $(a_2 + a_3)$, the elasticity of domestic and foreign demand with respect to relative prices, be less than one. If, in addition, output is always at its full employment level, $a_2 = a_3 = 0$, $\delta_1 = 0$, and the $De_t = 0$ schedule is vertical. This is exactly Dornbusch's fixed output model; the exchange rate always overshoots. The innovation in this model is that, even with fixed output, the exchange rate can undershoot. All that is necessary is that the degree of monetary accommodation to prices be sufficiently large, i.e., that

$a_7 + a_9 > 1$. Allowing output to respond to relative prices merely strengthens the case for undershooting.

The intuition behind these results is as follows. Because of the long run purchasing power parity assumption, the increase in the domestic steady state money supply ($\bar{m}$) increases the steady state exchange rate ($\bar{e}$) and price ratio ($\bar{q}$). Assuming that both countries' monetary policies accommodate price movements, this causes the component of the domestic money supply that responds to prices to decrease and the foreign money supply to increase.[24] First, consider the case where output is fixed. Remembering that prices are pre-determined, if monetary policy is sufficiently accommodative so that $a_7 + a_9 > 1$, the increase in the domestic steady state money supply causes a decrease in the money suply ratio ($m_t - m_t^*$). Asset market equilibrium then requires the domestic interest rate to exceed the foreign interest rate, which in turn is only consistent with expected (and actual by perfect foresight) exchange rate depreciation. Thus the exchange rate must jump (depreciate) to a point where it will continue to depreciate; it must undershoot.

These results are not as restrictive when output is flexible. Since output depends on relative prices, and the price ratio is pre-determined, an increase in $\bar{m}$, by causing an immediate depreciation of the exchange rate, will increase the relative price of foreign goods. This increases the ratio of domestic to foreign output ($y_t - y_t^*$). Output flexibility can substitute for accommodative monetary policy to produce exchange rate undershooting. It is no longer necessary that the increase in the steady state money supply produce a decrease in the money supply ratio, only that the increase in the money supply ratio be smaller than the increase in the output ratio. As above, asset market equilibrium then requires the domestic interest rate to exceed the foreign interest rate, which produces exchange rate undershooting.

IV. Empirical Results: The Deutsch Mark/Dollar Rate

The theoretical model derived above relates exchange rate behavior to activist monetary policy, in particular to the extent to which monetary policy accommodates price movements. In this section, the model is estimated for Germany and the United States, using quarterly data since the advent of generalized floating in 1973.

In order to estimate the model, it is necessary to derive the reduced form. First, substituting equations as in the perfect foresight solution, and interpreting all variables as deviations from their long run equilibrium values, we obtain:

$$(9) \qquad \begin{vmatrix} \hat{e}_{t+1} \\ q_{t+1} \end{vmatrix} = \begin{vmatrix} \delta_1 + 1 & \delta_2 \\ \delta_3 & \delta_4 + 1 \end{vmatrix} \begin{vmatrix} e_t \\ q_t \end{vmatrix} + \begin{vmatrix} u_{1t} \\ u_{2t} \end{vmatrix}$$

$$(10) \qquad y_t = a_2(e_t - q_t) + u_{3t}$$

$$(11) \qquad y_t^* = -a_3(e_t - q_t) + u_{4t}$$

$$(12) \qquad m_t = a_6 e_t + a_7 q_t + u_{5t}$$

$$(13) \qquad m_t^* = -a_8 e_t - a_9 q_t + u_{6t}$$

where the u's are combinations of the ε's.

Before proceeding further, we need to make some assumption about the structure of the error terms. We assume that they are generated by second order autoregressive processes, i.e., $u_{jt} = \alpha_{j1} u_{jt-1} + \alpha_{j2} u_{jt-2} + \eta_{jt}$, $j = 1, \ldots, 6$, where the η's are serially uncorrelated. Since, in order to derive the reduced form, the error terms must be finite moving average processes, we take the infinite moving average processes implicit in the above autoregressive processes and truncate them appropriately.[25]

To derive the reduced form for equation (9), assume that expectations are determined rationally and solve by the method of undetermined coefficients to obtain:

$$\begin{vmatrix} e_t \\ q_t \end{vmatrix} = A \begin{vmatrix} e_{t-1} \\ q_{t-1} \end{vmatrix} + B(L) \begin{vmatrix} \nu_{1t} \\ \nu_{2t} \end{vmatrix} \tag{14}$$

where A and B are 2 × 2 matrices.

The derivation of (14) is straightforward but tedious.[26] The elements of A and B are non-linear combinations of the δ's and the α's. The ν's are combinations of the η's, written so as to make the zero lag coefficient matrix the identity matrix. The constraints on the parameters are caused by the form of the structural equations, the assumption of rational expectations, and the stability condition necessary to achieve a unique solution.[27]

The model to be estimated consists of equations (10)-(14). By truncating the implicit moving average representation of the disturbances at third order for u_1 and fourth order for the others, a first order autoregressive fourth order moving average model is derived. Maximum likelihood estimates (conditional on the initial disturbances being set equal to zero) are obtained under the assumption that $(\nu_{1t}\ \nu_{2t}\ u_{3t}\ u_{4t}\ u_{5t}\ u_{6t})'$ is multivariate normal.[28] The policy $(a_6 - a_9)$ and structural $(a_1 - a_5)$ parameters are jointly estimated. This, combined with the imposition of rational expectations, satisfies several aspects of Lucas' (1976) critique of econometric policy evaluation.[29]

As described above, the model is estimated for the United States and Germany, using quarterly data for 1973(II)-1981(IV).[30] Real GNP is used to measure output, and M1 for the money supply. It is not clear what is the appropriate measure for the price level. While the GNP deflator is the best aggregate for the money demand equation, the wholesale price index (WPI) is a

better proxy for traded goods prices, and thus a better measure for relative prices. Since, in addition, there did not seem to be any reason why monetary policy should respond identically to the two measures, we performed the estimation with both.[31]

The maximum likelihood estimates of the structural ($a_1 - a_5$), policy ($a_6 - a_9$), and serial correlation (α_{ij}) parameters are given in Table 1 along with their asymptotic "t-ratios," the ratio of the coefficients to their standard errors computed from the inverse of the second derivative matrix of the likelihood function. Germany is taken as the domestic country, so that a_6 is the response of the German money supply to the exchange rate, a_7 the response of the German money supply to the price ratio, $-a_8$ the response of the American money supply to the exchange rate, and $-a_9$ the response of the American money supply to the price ratio.

The most noteworthy aspect of the estimates is that both δ_1 and δ_2 are positive for the two measures of the price level, implying exchange rate overshooting.[32] The policy parameters that produce this result are quite different, however, for the two price level measures. For the wholesale price index, the money supply is not responsive to either the exchange rate or the price ratio. All four coefficients ($a_6 - a_9$) are small, and only one, the response of the American money supply to the exchange rate, is significant. For the GNP deflator, while American monetary policy is very accommodative of prices, German policy is sufficiently offsetting so that the combined policies are not accommodative enough to produce undershooting. German monetary policy also offsets exchange rate movements. American monetary policy is unresponsive to the exchange rate. Variable output is insufficient to produce undershooting. The sum of the coefficients of relative prices in the output

equations ($a_2 + a_3$) is very small for the GNP deflator and not large enough to matter for the WPI.[33]

Neither Dornbusch's nor Mussa's price equation receives much support from the estimates, since a_4 is negative in both cases. (a_4 equals zero in Dornbusch's and one in Musa's specifications.) Although a_4 is quite small, especially for the GNP deflator, the values for δ_3 and δ_4 are very different from those that could have been generated from Dornbusch's formulation (where $\delta_3 = -\delta_4$).[34] The coefficient of relative prices in the price adjustment equation (a_5) and the interest rate semi-elasticity of the demand for money (a_1) are of the expected sign. For the WPI, while these structural parameters are almost all of the expected sign and magnitude, they are at best borderline significant. For the GNP deflator, while they are all significant, a_1 is implausibly small. We investigate this further below.

The estimates are generally more successful for the GNP deflator than for the WPI. For the GNP deflator, all of the structural, and all but one of the policy, coefficients are significant. Activist monetary policy, while not producing undershooting, is clearly important in the determination of the Deutsche Mark/Dollar rate. For the WPI, several of the structural coefficients are of questionable significance, and the policy coefficients are generally insignificant. Activist monetary policy does not seem to matter very much.

A number of the other features of the estimates are worth mentioning. The correlations between the estimated and actual values of the variables are fairly high. There is one stable root and one unstable root in each case, indicating that the stability condition is sufficient to provide a unique solution. A formal test of the model is provided by estimating an "unconstrained" version. This imposes the same policy equations and serial

correlation structure as the constrained version, but does not impose the forms of the structural equations or the rational expectations restrictions. By comparing the log-likelihoods of the constrained and the unconstrained models, we construct a likelihood ratio test. While the likelihood ratio test rejects the constrained model in comparison with the unconstrained for both cases, the estimates involving the GNP deflator come much closer to not being rejected. The rejection of the constrained model for the WPI accords with Driskill and Scheffrin's (1981) findings for Frankel's model.[35]

It is illustrative to compare these results with those obtained from estimating a somewhat less constrained model. In this "semi-constrained" version, the δ's are left unrestricted, but all of the other constraints of the model are imposed. This breaks the previously imposed linkage between the magnitude of the policy parameters ($a_6 - a_9$), the magnitude of the elasticities of demand with respect to relative prices (a_2 and a_3), and the question of overshooting. While all of the equations are still jointly estimated, the policy parameters (as well as a_2 and a_3) now only enter into equations (10)-(13). They do not affect the reduced form of equation (14). Since these parameters do not affect the estimates of e and q, they are irrelevant for considering overshooting.

The maximum likelihood estimates of the semi-constrained model are presented in Table 2. They provide strong support for the overshooting results implied by the constrained estimates. The values of δ_1 and δ_2 are positive in both cases, and the significance levels are high.[36] The signs and magnitudes of the structural and policy parameters are quite similar between the constrained and semi-constrained models in both cases. These results indicate that the finding of overshooting for the constrained model is not simply a construct imposed by the restrictions on δ_1 and δ_2 and the magnitudes

of the policy parameters. Another way of considering the results is that, given the finding of overshooting from the semi-constrained model, the estimates of the constrained model are consistent with the theoretical hypotheses on the affects of activist monetary policy. This perspective can be evaluated more formally by considering likelihood ratio tests. Comparing the log-likelihoods of the constrained and semi-constrained models, we cannot reject the constrained model at standard significance levels.[37] This indicates that the rejection of the constrained when compared with the unconstrained model is caused by the assumption of rational expectations and imposition of the stability condition necessary to guarantee a unique solution, not by the form of the structural equations.

One of the characteristics of the estimates for the GNP deflator is that, since a_2 is approximately equal to $-a_3$, variable output is virtually irrelevant. With this in mind, we estimated a variant of the model where output, assumed to be constant, does not appear once deviations are taken from the steady state. This can be thought of as taking the model described by equations (10)-(14) and setting a_2, a_3, and their associated δ's equal to zero. The estimates of this are presented in Table 3. The values and significance levels of the parameters are quite similar to those in Table 1, and the exchange rate again overshoots. One advantage of this variant is that, with six fewer parameters to estimate, the power of the likelihood ratio test is increased. While the constrained model can still be rejected when compared with the unconstrained model at standard significance levels, it comes much closer to not being rejected than the model which includes output.[38]

The final aspect of the estimates for the GNP deflator that we investigate is the role played by the implausibly small estimate of the

interest rate semi-elasticity of the demand for money (a_1). To accomplish this, we first estimate (1) using a single equation method.[39] This allows us to utilize interest rate data (we use three-month money market rates for Germany and the United States)[40] and provides an estimate for a_1. The estimate (.54) is much more in accord with work on the demand for money than the estimates of a_1 in Tables 1 and 3. We then estimate the full model (including output) as above, with the additional constraint that $a_1 = .54$. The estimates of this model are presented in Table 4. The only coefficients that change very much are those in the price adjustment equation (a_4 and a_5), and they change so as to keep the values of δ_3 and δ_4 exactly equal to their magnitudes in Table 1. This again highlights the desirability of further investigation of the price adjustment process. The overshooting results are unaffected. δ_1 and δ_2 are both positive, although much smaller than in Table 1.[41]

V. Conclusions

This paper shows that, in the context of a model with perfect capital mobility and slow price adjustment, monetary policy that accommodates price movements has the potential to cause exchange rate undershooting. It extends earlier work, which focused on imperfect capital mobility and variable output, to provide another reason why overshooting is not an intrinsic characteristic of the foreign exchange market. It also provides strong econometric evidence that, for the current flexible rate period, the Deutsche Mark/Dollar exchange rate does exhibit overshooting. This occurs both with the Wholesale Price Index, where there is little price responsiveness to either country's monetary policy, and with the GNP deflator, where, while American monetary policy is highly accommodative to prices, German monetary policy is sufficiently offsetting to cause overshooting.

FOOTNOTES

[1]Flood (1981) and Leiderman (1982) provide recent evidence of this.

[2]Dornbusch also showed how variable output would eliminate the necessity of overshooting. We will consider variable output in Section III. Calvo and Rodriguez (1977) showed how overshooting could occur with perfectly flexible prices and imperfect capital mobility. Levich (1981) surveys and analyzes several types of overshooting models. We will not consider overshooting models of other than the Dornbusch type in this paper.

[3]If disturbances are anticipated in Dornbusch's model, as in Wilson (1979) or Gray and Turnovsky (1979), the initial depreciation can be below the steady state, followed by further depreciation above the long run equilibrium, and finally by appreciation back to the steady state. Since the exchange rate, at some point, depreciates by more than its long run equilibrium depreciation, this is an example of overshooting.

[4]Activist monetary policy has been studied for its effect on output and price variability in a closed economy context by Taylor (1980) and in an open economy context by Leiderman (1981), Rehm (1982), and Taylor (1982). Flood (1981) considers activist monetary policy (in the sense of interest rate stabilization) and exchange rate volatility, but in a context where observers do not correctly perceive the money supply rule.

[5]The stochastic version of this model contains a number of implications regarding the effect of activist monetary policy on exchange rate variability. These will be tested, in the context of that model, in a subsequent paper.

[6]By assuming perfect capital mobility and by not incorporating lags in the output and/or the money supply equations, we restrict the model to a system of two first-order difference equations. This simplification allows us to derive straightforward theoretical results using graphical solution techniques. A complementary modeling strategy is to first specify a model that is too complicated to be solved analytically, gain insight into the workings of the model through simulation, and then estimate it. While this would be superior econometrically, the method used in the paper results in clearer theoretical propositions.

[7]The theoretical results would not have been affected if they were presented in a single, small country model. The two-country framework was chosen to econometrically incorporate both countries' money supply rules and to avoid making exogeneity assumptions regarding "foreign" interest rates, output, and prices.

[8]The assumption that the interest rate semi-elasticities of the demand for money are identical in the two countries, while not very satisfactory, seems to be unavoidable without greatly complicating the model. Frankel (1979) and Driskill and Sheffrin (1981) make the same assumption.

[9]Mussa (1982) argues that the appropriate deflator for nominal balances is a weighted average of domestic and foreign goods price levels (denominated

in domestic currency). With the income elasticities of the demand for money equal to unity, this, as shown by Flood (1981), does not affect Equation (1). We do not incorporate the effect of the exchange rate on the domestic goods price level through imports of intermediate goods.

[10]It would be preferable to allow lags in the output equation, but this greatly complicates the model. Allowing each country's output to depend on the real interest rate and/or the other country's output does not substantially affect the results. While the exact conditions for over and undershooting are not identical, they do not change enough to make much difference.

[11]The assumption that output is demand determined is made for comparison with Dornbusch's work. A model with a Lucas type aggregate supply function could yield an identical reduced form.

[12]Mussa's argument is that his formulation has both a better microeconomic rationale and more sensible steady state properties than Dornbusch's formulation.

[13]The assumption of pre-determined prices allows us to put actual (p^*_{t+1}) instead of expected ($\hat{p}^*_{t+1}$) foreign prices in equation (4c). The equilibrium price level ($e_t + p^*_t$) clears the goods market in the short run and is consistent with long run purchasing power parity. Engle and Frankel (1982) and Glaessner (1982) have used similar specifications of Mussa's formulation.

[14]In addition, the money supply could have been postulated to depend on the interest rate differential which, in this model, is equivalent to the expected rate of depreciation. The issues raised in that formulation are discussed in Papell (1983). Allowing lags in the money supply equations greatly complicates the analysis.

[15]Sources of error in the money supply processes from having prices not pre-determined, as in Flood and Hodrick (1982), or the monetary authorities not being able to use all of the information contained in the contemporaneous exchange rate can be subsumed in ε_4 and ε_5.

[16]The money supply could be allowed to respond separately to domestic and foreign price levels if we were willing to assume that the policy coefficients were identical across the two countries. This assumption seems less tenable than the one made in the paper, and is not supported by the empirical results.

[17]Cumby and Obstfeld (1982) find that Germany is the only country (out of five tested) where uncovered interest rate parity cannot be rejected vis-a-vis the United States. While Hansen and Hodrick (1982) find statistically significant risk premia between the forward and the expected future spot rate, their evidence indicates that these risk premia are small. In Papell (1983) imperfect capital mobility is modeled as a flow adjustment process (as in Frenkel and Rodriguez (1982)) to investigate overshooting of the effective exchange rate for Germany and Japan. Modeling imperfect capital mobility as a stock adjustment process greatly complicates the analysis.

[18]By "the money supply," we mean the sum of the coefficients of the domestic (a_6) and foreign (a_8) money supplies.

[19]We do not consider the possibility, studied by Calvo (1981), that a devaluation would decrease domestic income, thus making $\delta_1 < 0$. While this "contraction-devaluation" case is more appropriate for his focus on "southern cone" countries operating managed exchange rates than for our focus on flexible exchange rates, it is interesting to note that the "contraction-devaluation" case could produce non-uniqueness in our model as well as in his. We will explore these issues in a subsequent paper.

[20]While these diagrams are more common in continuous time, Mussa uses them in a discrete time model. The theoretical results here are presented in discrete time for comparison with the empirical work in Section IV.

[21]Incorporating anticipated disturbances does not change the results as long as overshooting is interpreted as occurring at some point in time, as in footnote 3, rather than necessarily on impact.

[22]In general, an increase in the domestic money supply will also shift the $Dq_t = 0$ schedule to maintain long run purchasing power parity. For the particular case illustrated ($a_3 = 0$), the movement along the $Dq_t = 0$ schedule restores the steady state equilibrium.

[23]The diagram illustrates the case where $|\delta_2| < \delta_1$. If monetary policy was even more accommodative, so that $|\delta_2| > \delta_1$, exchange rate undershooting would still occur.

[24]In order to see this, note that equations (5) and (6) can be written (with perfect foresight) as:

$$(5) \quad m_t = \bar{m} + a_6(e_t - \bar{e}) + a_7(q_t - \bar{q})$$

$$(6) \quad m^*_t = \bar{m}^* - a_8(e_t - \bar{e}) - a_9(q_t - \bar{q})$$

Since q_t is pre-determined, the increase in $\bar{q}$ produces an immediate decrease in the component of m_t that depends on $(q_t - \bar{q})$ and an increase in m^*_t.

[25]The advantage to using this procedure rather than starting directly with the finite order moving average representation is that it reduces the number of parameters to be estimated without particularly constraining the system.

[26]The derivation is available from the author upon request. The model can, of course, be solved by other methods, such as in Blanchard and Kahn (1980).

[27]The system has two roots, λ_1 and λ_2. In order for there to be a unique solution, one of the roots must be stable (< 1) and one unstable (> 1). The stability condition consists of setting the coefficient of the unstable root equal to zero. This is equivalent to restricting the economy to be on the saddle path after a disturbance.

[28]More detail on the econometric method can be found in Taylor (1980).

[29]The model clearly does not satisfy other aspects of the Lucas critique, such as concern that macroeconomic models be derived from utility maximization of individual agents.

[30]To be exact, we started with data from 1973(I)-1981(IV) and, since one observation is "lost" in estimating an ARMA(1, 4) model, performed the estimation over the described period.

[31]The exchange rate used was the quarterly, period average rate, taken from International Financial Statistics. End-of-period rates were also tried; they made little difference. The money supply was end-of-period, also taken from IFS. It was felt that end-of-period money supply data would be a better measure of within period responsiveness to exchange rates and prices than period averages. The other data were taken from Survey of Current Business (United States) and Deutsche Bundesbank (Germany). All data, except for the exchange rate and the WPI, was seasonally adjusted. In order to achieve stationarity, all variables, after taking logarithms, were detrended by regression on a constant and linear time trend.

[32]The concept of overshooting, as defined by Dornbusch, describes the behavior of the exchange rate after a permanent increase in the money supply, while for the empirical work, all disturbances are temporary. In this context, overshooting should be interpreted as the existence of estimated parameter values such that, in the deterministic model, a permanent increase in the money supply would cause exchange rate overshooting. Flood (1981) and Levich (1981) discuss other definitions of overshooting in a stochastic context. These are related to concepts of exchange rate volatility, and do not necessarily correspond to Dornbusch's concept of overshooting.

[33]The signs of the coefficients (a_2 and a_3) in the output equations are puzzling. Both German and American output declined (relative to trend) in 1974-75 and 1980-81, following the two major oil price increases, and increased in 1976-79. Assuming that the oil shocks dominated relative price effects, this can account for a_2 and a_3 being of opposite sign, but not for the sign reversal between the estimates for the GNP deflator and the WPI. We experimented with including the other country's output in each country's output equation, but this neither changed the sign pattern for a_2 and a_3 nor improved the estimates.

[34]In an earlier version of the paper, we estimated the model with Dornbusch's price equation. The current formulation provides clearly superior econometric results. We also attempted to estimate the model with Mussa's equation, but could not get the estimates to converge at an optimum. Comparison of the constraints (δ_3 and δ_4) implied by either Dornbusch's or Mussa's formulations with those implied by the estimated values reveals large discrepancies, indicating the probable reason why these estimates were not successful.

[35]Let L(u) be the log of the likelihood function for the unconstrained model, L(c) the log of the likelihood function of the constrained model, u the number of parameters estimated for the unconstrained model, and c the number of parameters estimated for the constrained model. Then $2(L(u) - L(c))$ is

distributed chi-squared (u - c). The log of the likelihood function of the unconstrained model for the GNP deflator is 657.880, and for the WPI is 628.369. The unconstrained model contains 28 estimated parameters, indicating rejection of the constrained model at standard significance levels. These results should be interpreted with caution, however, since we have relatively few observations and the small sample properties of the likelihood ratio test are not well known. Driskill and Scheffrin (1981) hypothesize that one of the reasons their estimates fail the likelihood ratio test is the endogeneity of the German money supply. While our data and estimation techniques are not identical to theirs, our results clearly fail to support that conjecture. Another possibility is that the assumption of pre-determined prices is unwarranted. Glaessner (1982) estimates a similar model with an exogenous money supply and flexible prices for Canada which is also rejected by the likelihood ratio test. Models in which prices are neither flexible nor pre-determined, such as in the recent theoretical work of Flood and Hodrick (1982), provide another alternative for future empirical research.

[36]Both parameters are significantly different from zero for the GNP Deflator, and of borderline significance for the WPI.

[37]The semi-constrained model contains 22 parameters. With s - c = 1, $2[L(s) - L(c)]$ equals .42 for the GNP deflator, significant at the 50% level, and equals .71 for the WPI, significant at the 25% level.

[38]The log of the likelihood function for the unconstrained model, containing 20 parameters, is 413.180. With u - c = 5, $2[L(u) - L(c)]$ equals 12.11, significant at the 2.5% level.

[39]We use the ARI procedure of TSP, which provides efficient estimates of an equation whose disturbances display first order serial correlation.

[40]The interest rates were taken from World Financial Markets. They were detrended by regression on a constant and linear time trend.

[41]The constrained model is again rejected in comparison to the unconstrained by the likelihood ratio test.

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Table 1

Parameter	GNP Deflator Estimate	GNP Deflator Asymptotic "t ratio"	Wholesale Price Index Estimate	Wholesale Price Index Asymptotic "t ratio"
Constrained Maximum Likelihood Estimates				
a_1	.004	3.85	.22	1.55
a_2	.19	3.73	-.30	-2.25
a_3	-.22	-3.65	.48	3.22
a_4	-.007	-3.99	-.09	-1.56
a_5	.40	2.51	.03	1.39
a_6	-.24	-5.05	-.03	-.53
a_7	-2.71	-8.42	.14	1.00
a_8	-.01	-.25	.08	2.24
a_9	3.49	10.73	.11	.90
α_{11}	.86	7.71	1.82	6.67
α_{12}	-.11	-.81	-1.58	-3.22
α_{21}	.35	3.98	.60	4.66
α_{22}	.36	4.29	-.29	-2.83
α_{31}	.92	14.15	.75	6.96
α_{32}	-.03	-.33	.19	1.49
α_{41}	.28	3.29	.27	2.36
α_{42}	.39	4.51	.16	1.67
α_{51}	1.05	7.23	1.06	9.08
α_{52}	-.29	-1.79	-.41	-4.32
α_{61}	1.12	10.31	1.11	10.72
α_{62}	-.42	-3.91	-.42	-5.02
Parameter Values Implied by the Estimates				
δ_1	53.10		.59	
δ_2	60.35		3.86	
δ_3	.03		-.02	
δ_4	-.82		-.38	
Correlation Between Actual and Estimated Values				
e	.84		.79	
q	.87		.80	
m	.95		.93	
m*	.83		.76	
y	.89		.90	
y*	.89		.91	
Log Likelihood				
	645.215		610.446	

Table 2

Parameter	GNP Deflator Estimate	GNP Deflator Asymptotic "t ratio"	Wholesale Price Index Estimate	Wholesale Price Index Asymptotic "t ratio"
Semi-Constrained Maximum Likelihood Estimates				
δ_1	477.20	17.02	.63	1.93
δ_2	477.64	15.40	2.72	1.73
δ_3	.03	15.68	-.02	-1.03
δ_4	-.85	-18.96	-.29	-2.09
a_2	.20	3.34	-.29	-2.03
a_3	-.23	-2.95	.54	2.90
a_6	-.22	-3.15	-.10	-1.00
a_7	-2.64	-3.98	.18	.99
a_8	-.01	-.22	.07	1.80
a_9	4.15	4.47	.13	1.01
α_{11}	.88	24.57	1.79	7.01
α_{12}	-.13	-13.55	-1.53	-3.34
α_{21}	.35	4.04	.63	4.37
α_{22}	.37	4.12	-.28	-2.87
α_{31}	.91	13.70	.81	6.84
α_{32}	-.01	-.13	.11	.80
α_{41}	.29	3.30	.27	2.39
α_{42}	.39	4.26	.18	1.75
α_{51}	1.07	24.57	1.06	9.09
α_{52}	-.31	-13.55	-.41	-4.31
α_{61}	1.13	10.88	1.12	11.20
α_{62}	-.43	-4.39	-.42	-5.25
Correlation Between Actual and Estimated Values				
e	.84		.78	
q	.87		.80	
m	.95		.92	
m*	.83		.76	
y	.89		.90	
y*	.89		.91	
Log Likelihood				
	645.427		610.801	

Table 3

GNP Deflator

Constrained Maximum Likelihood Estimates

Parameter	Estimate	Asymptotic "t ratio"
a_1	.003	17.70
a_4	-.008	-6.11
a_5	.76	5.77
a_6	-.24	-6.24
a_7	-2.53	-13.68
a_8	-.02	-.22
a_9	3.52	19.24
α_{11}	.90	6.68
α_{12}	-.13	-.83
α_{21}	.34	4.21
α_{22}	.41	4.70
α_{31}	.92	14.82
α_{32}	-.01	-.18
α_{41}	.35	3.86
α_{42}	.41	4.19

Parameter Values Implied by the Estimates

δ_1	87.23
δ_2	5.27
δ_3	.02
δ_4	-.80

Correlation Between Actual and Estimated Values

e	.84
q	.87
m	.95
m*	.84

Log Likelihood

407.125

Table 4

GNP Deflator

Constrained Maximum Likelihood Estimates

Parameter	Estimate	Asymptotic "t ratio"
a_2	.21	3.24
a_3	-.25	-2.94
a_4	-.70	-1.44
a_5	.28	1.58
a_6	-.23	-3.45
a_7	-2.84	-5.96
a_8	.001	.02
a_9	3.46	7.05
α_{11}	1.00	3.27
α_{12}	-.05	-.15
α_{21}	.37	3.94
α_{22}	.35	3.93
α_{31}	.91	12.95
α_{32}	-.03	-.29
α_{41}	.29	3.24
α_{42}	.38	4.26
α_{51}	1.06	7.40
α_{52}	-.30	-1.94
α_{61}	1.12	10.14
α_{62}	-.43	-4.03

Single Equation Estimates

$-a_1$	-.54	-2.31

Parameter Values Implied by the Estimates

δ_1	.35
δ_2	.77
δ_3	.03
δ_4	-.82

Correlation Between Actual and Estimated Values

e	.83
q	.87
m	.95
m*	.83
y	.89
y*	.88

Log Likelihood

643.271

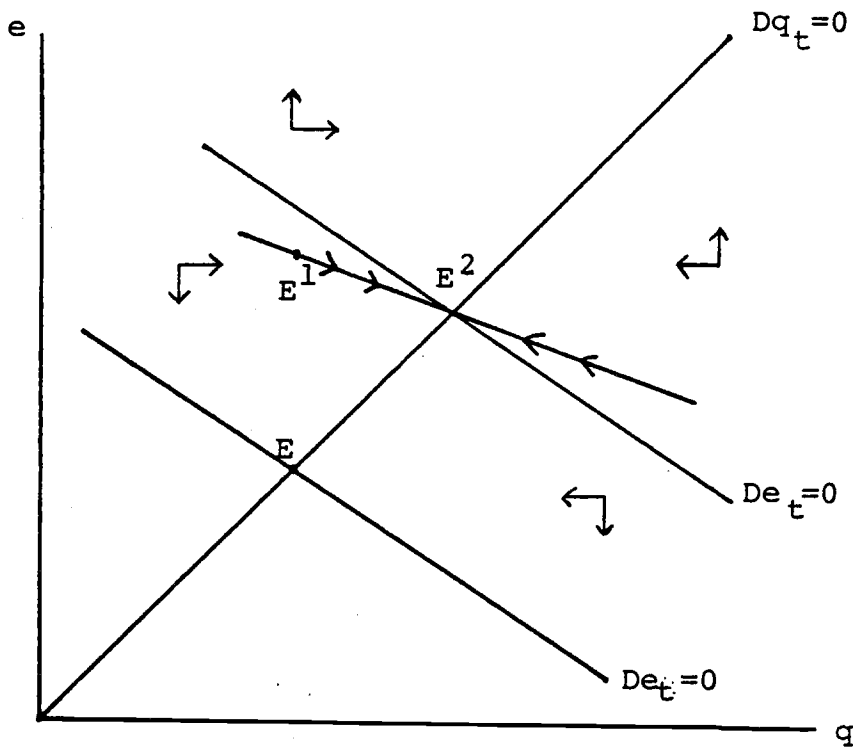

Figure 1

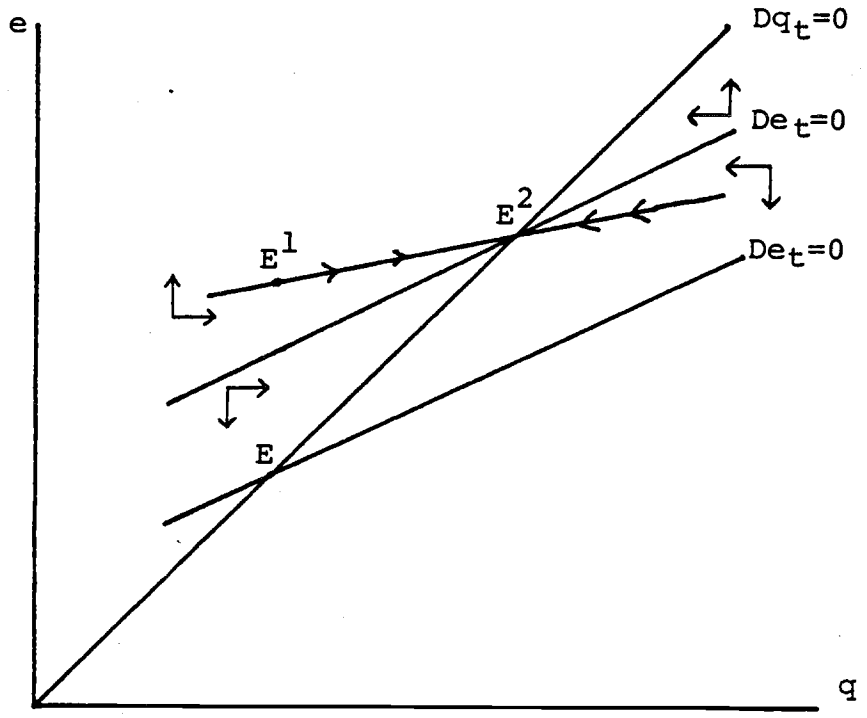

Figure 2