EXPECTATIONS, EXCHANGE RATES AND MONETARY THEORY

THE CASE OF THE GERMAN HYPERINFLATION

by

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1. Introduction:

The aim of this paper is to examine the behavior of the foreign exchange markets during the German hyperinflation and test some implications of the monetary theory of exchange rates. In his study of inter-war European hyperinflations, Cagan (1956) presented convincing evidence that all the hyperinflations were monetary in nature and that in spite of the extreme and chaotic economic conditions that prevailed it is possible to identify a stable demand for money schedule that depends only on variables dictated by economic theory. One of the features of a hyperinflation is that the magnitude of the monetary disturbance is likely to dominate any concurrent real changes in the economy and thereby facilitate tests of monetary theory. Even so, these is always the question as to the applicability of such studies of hyperinflations to more stable conditions.

The core of the monetary theory of prices and exchange rates centers around the demand for real cash balances and the equalization of the purchasing power of different monies. Just as the interaction of the real demand for money and the nominal supply of money determines the price level of each country, the interaction of the demand for and supply of money between any two countries determines their respective exchange rates. The empirically testable implication is that coefficient estimates, such as income and interest elasticity, from the appropriate exchange market equation should be the same as those from the respective demand for money equations. The results of this test is the central contribution of the paper.

The results broadly support the monetary theory. However, exchange rates are found to be statistically more volatile than goods prices;

this volatility is not explained by current theories. Due to the lack of interest rate data, a direct comparison between the monetary theory and the generalized asset approach is not possible. I only present some weak evidence of the absence of some effects predicted by the asset approach.

Extreme monetary models deny that variables such as the balance of trade, reparation payments and even central bank intervention have any significant effect on the relative price of monies beyond their effect through the quantity of money. These variables are explicitly tested here. Only central bank intervention appears to have a strong but temporary effect on exchange rates.

The question of exchange market efficiency has been researched extensively. The typical procedure is to test whether the coefficient of the forward rate when regressed on its correseponding spot rate is statistically different from unity and whether the error term shows significant autocorrelation. As reported in Frenkel (1976), the results of this test are ambiguous for the German hyperinflation data. In this paper I report tests of the hypothesis that the spot and forward rates are generated by the identical underlying structural model. This jointly hypothesis test supports the proposition that exchange markets are efficient and helps explain the ambiguous results of prior tests.

The paper is divided into five sections. Section two describes the relation between the spot and forward exchange rates and reports some standard efficiency tests for these markets. Section three develops a simple monetary model with exogenous real income and extends the model to incorporate a spot and forward market for foreign exchange. The following sections present tests of some implications of the monetary theory of exchange rates, compare alternative theories and provide an explanation for apparent inefficiencies reported in section two.

2. Efficiency in the Foreign Exchange Market:

The model to be discussed below relies on continuously clearing, competitive and efficient asset markets, including the exchange markets. Since identification of severe inefficiencies would imply that such equilibrium theories of exchange rate determination are not applicable, market data should first be confronted with some general efficiency tests.

This section reviews the evidence on the efficiency of the foreign exchange markets during the hyperinflation. Frenkel (1976) reports some results supporting the notion that the markets were efficient during this period. Here these results are extended and appraised.

The methodology employed here follows the literature in viewing the current one period forward rate (F_t^1) as a forecast of the future spot rate, (S_t);

$$\text{(1a)} \qquad F_{t-1}^1 = E_{t-1}(\tilde{S}_t)$$

If expectations are on average correct, then the current spot rate is

$$\text{(1b)} \qquad \tilde{S}_t = E_{t-1}(\bar{S}_t)\ \tilde{X}_t$$

$$\text{(1c)} \qquad \tilde{X}_t = \exp\{\tilde{x}_t - \frac{\sigma_x^2}{2}\}; \quad \tilde{x}_t \sim \tilde{N}(0, \sigma_x^2) \quad \text{so that} \quad E(\tilde{X}_t) = 1.0$$

where $\bar{S}_t$ is the mean of the underlying distribution and $\tilde{X}_t$ is a lognormally distributed normalized random disturbance. Combining (1a) with (1b) and taking logs yields:

(2a) $\tilde{s}_t = f^1_{t-1} + \tilde{x}_t - \frac{\sigma^2_x}{2}$

The market efficiency hypothesis imbedded in (2a) can be tested by regressing last period's forward rate to the current spot rate and testing whether b_1=1.00 and $b_o = \frac{\sigma^2_x}{2}$.

The estimation results with monthly data from the German hyperinflation period are (standard errors in parenthesis):[1]

(2b) $\tilde{s}_t = b_o + b_1 f^1_{t-1} + \tilde{x}_t$

b_o = -0.256 (0.300) b_1 = 1.068 (0.034)

$\frac{\sigma^2_x}{2} = 0.106$ $R^2 = .974$ Q = 7.40   DW = 2.03

The constant $(\hat{b}_o)$ is not sufficiently different from zero nor from $-\sigma^2_x/2$ at any reasonable confidence level. The slope coefficient is not sufficiently different from unity at the 95% confidence level as well. These results are similar to those obtained by Frenkel (1977) with the exception that the slope coefficient he calculates is statistically greater than unity[2]. A very important empirical finding in both papers is that there is very low autocorrelation in the residuals as indicated by both the Durbin-Watson coefficient and the Box-Pierce (Q) statistic. None of the autocorrelations are significant and only the one at lag-4 exceeds 1.00 standard deviation. This indicates that easily available information could not have been used to improve the forecasts. An examination of $s_t - f^1_{t-1}$ yields the same results, where constraining b_1 to unity eliminates the bias towards accepting the null hypothesis of no autocorrelation when b_1 is estimated.

I have also examined the autocorrelation structure of the difference between the forward rate and the future spot rate (the prediction error) from weekly data by estimating several univariate, autoregressive-moving average (ARMA) models.[3] The reason for this procedure is that in weekly data, the first three autocorrelations will be high, since the time intervals between any two successive one-month ahead forecasts overlap. At week t the market issues a forecast F_t^4 for S_{t+4}; at week t+1, F_{t+1}^4 is a forecast of S_{t+5}. These two forecasts have a 3 week interval in common and they will be highly autocorrelated. $S_{t+4} - F_t^4$ and $S_{t+8} - F_{t+4}^4$ should not be autocorrelated at all. In an efficient market, the first three autocorrelation coefficients of the ARMA (0,0) model of the predicted errors will be high, while all others should be zero. Therefore, the first three moving average coefficients of an ARMA (0,4) model should be significantly different from zero while the fourth coefficient and all the autocorrelation coefficients of the new residuals should be zero. These predictions are upheld as can be seen from the autocorrelation structure of the ARMA (0,0) model or the coefficient estimates of the ARMA (0,4) model reported in Table 1.[4] The evidence suggests that the efficiency hypothesis cannot be rejected.

Figure 1 is a plot of the forward rate versus the spot rate one period hence and is also discussed in Frenkel (1977). The disturbing aspect of this plot is that, not unlike current experience, the forward rate seems always to lag the spot rate. To see whether this observation is statistically important, I reestimate (2b) with a dummy variable in the slope coefficient as well as the intercept. The dummy variable (Δ) is +1.0 when the market predicts a depreciation of the currency i.e., the forward rate is at a discount, and zero when it predicts an appreciation; Δ reflects only information available at t. The results are presented in Table 2. Regression (4) appears to most closely fit the data. The implication of (4) is that like regression (1) there is no statistically significant constant bias between forward and spot rates, whether the spot rate is expected to appreciate or depreciate. When the expectation is the the spot rate will appreciate, the elasticity of the forecast is undistinguishable from unity; in six out of the thirty-one months the forward rate indicates an expected appreciation. However, when the expectation is that the spot rate will depreciate the elasticity is greater than unity implying that over the period in question the forward rate consistently underestimates the future spot rate. No significant autocorrelation is observed in the residuals.

The evidence on market efficiency presented in this section is mixed. The most persistent result is that simple extrapolation of past prediction errors would not have improved forecasts. The evidence also indicates that during periods of exchange rate depreciation, the forward rate systematically underpredicts the spot rate. The implied contradiction between the tests above is a result of the low power of the standard efficiency test used. The following sections develop a structural model of the spot and forward rates and shed more light on the question of efficiency.

3. The Model

The analysis assumes the semilog demand for money function used by Cagan (1956)

$$\tilde{m}_t^d = -\alpha(R_t^e+\pi_t^e) + y_t + p_t - \gamma' - \tilde{u}_t' \tag{3}$$

where m, y, p are the logs of money balances, real income and the price level respectively, R_t^e is the equilibrium expected real rate of return, π_t^e is the expected inflation rate, γ' is a constant and α is the interest semi-elasticity; $\pi_t^e = p_{t+1}^e - p_t$. $\tilde{u}_t'$ is a disturbance term.

Let the forward lead operator Γ be defined as $\Gamma^j X_t \equiv X_{t+j}^e$. Then (3) becomes:

(4) $$\tilde{m}_t^d = [(1+\alpha) - \alpha\Gamma]p_t + y_t - \alpha R_t^e - \gamma' - \tilde{u}_t'$$

(5) $$\tilde{p}_t = \frac{1}{1+\alpha-\alpha\Gamma}[m_t^d - y_t + \alpha R_t^e + \gamma' - \tilde{u}_t']$$

Assuming continuously clearing money markets and expanding yields:

(6) $$\tilde{p}_t = \theta \sum_{j=0}^{\infty} (1-\theta)^j [m_{t+j}^{e(t)} - y_{t+j}^{e(t)}] + \sum_{j=0}^{\infty} (1-\theta)^j R_{t+j}^{e(t)} + \gamma + \tilde{u}_t$$

where $m_{t+j}^{e(t)}$ indicates that forecasts of the money supply m_{t+j} are conditional on the information available at time t only; $\theta \equiv \frac{1}{1+\alpha}$, $\gamma = \gamma'(1+\alpha)$ and $\tilde{u}_t = \frac{1}{1+\alpha-\alpha\Gamma}\tilde{u}_t'$. Economic actors are assumed rational in that they use (6) to forecast future price levels. Within this general framework, particular expectations specifications along with actual money supply paths will uniquely determine the path of the price level; the real variables y_{t+j}^e and R_{t+j}^e are assumed to be independent from the monetary process.

There are currently two distinct though not necessarily contradictory stock models of exchange rate determination. One model elaborated by Mundell (1967), Johnson (1971), Frenkel (1976) and others is generally referred to as the monetary approach and focuses on a generalized form of the law of one price, the Purchasing Power Parity (PPP) doctrine. In this model, the price level of each country is determined by the demand for and supply of money. Since the price levels are equalized through trade, the spot rate can be written as a function of the demand for and supply of money in both countries while the forward rates are determined through Interest Rate Parity (IRP). The effects of changes in interest rates, inflation rates and other macroeconomic variables can only influence the spot rate through their impact on the respective money market equilibria. The forward rate has no direct role in this model. The usual assumption is that speculative activity will insure that the forward rate equals the expected future spot and is equivalent to assuming that the risk-adjusted, uncovered expected real rates of return are equalized across all securities and that exchange rate uncertainty has no undiversifiable component.

The alternative model by Niehans (1975), Dornbusch (1976) and others focuses on the equilibrium conditions of all the asset markets. The demand for and supply of all assets directly affect the exchange rate. The forward premium, the spot rate and the uncovered rates of return of all assets are simultaneously set so as to clear the asset markets. In this model, changes in the supply of any security have a direct impact on exchange rates in addition to the effect that works through the velocity of money. The forward rate is again assumed to equal the expected spot rate on a risk-adjusted basis. Unlike the monetary approach, this assumption does not imply that risk-adjusted, uncovered expected real rates of return are equalized. The reason is that the law of one price does not hold in the short run, either because the two country goods are not perfect substitutes, prices are not fully order to close the system it is necessary to make the assumption that the law of one price is expected to hold sometime in the future, which is equivalent to the assumption that the real rates of return will be eventually equalized. Changes in the supply of an asset result in systematic short run deviations of the spot rate form its PPP value, allowing real rates of return to differ in the short run while the expected future value of the currency is determined by the expectation that PPP will hold in the future. It is this feature that Dornbusch (1976) termed the "magnification effect".

A simple version of the asset model can be constructed in the following way: Assume that the one period forward rate ($\tilde{F}^1_t$) will not differ from the expected spot (S^e_{t+1}) by more than a random error term $\tilde{\varepsilon}_t$ and possibly a risk premium (ρ), which arises from the equilibrium pricing of all risky assets and does not depend on small changes in the supply of forward contracts[5].

(7) $$\tilde{f}^1_t = s^e_{t+1} + \rho + \tilde{\varepsilon}_t$$

where the variables are in natural logarithms.

(8) $$\tilde{f}^1_t - \tilde{s}_t = R^e_t + \pi^e_r - R^{*e}_t - \pi^{*e}_t$$

In the Interest Rate Parity relationship above, the nominal interest rates are expressed in terms of their components ("*" denotes foreign country variables). Note that (8) is only a statement that the supply of arbitrage funds is infinitely elastic and does not imply causality in any direction.[6] Combining (7) and (8) yields the equation that determines the current spot rate

$$(9) \qquad \tilde{s}_t = s^e_{t+1} - (\pi^e_t - \pi^{*e}_t) - (R^e_t - R^{*e}_t) + \rho + \tilde{\varepsilon}_t$$

placing emphasis on the importance of expectations as well as the simultaneity of the determination of prices and exchange rates.

(9) can be expanded by assuming that adjustments to PPP are known to be completed within i periods;

$$(10) \qquad s^e_{t+1} = A + \theta \sum_{j=0}^{\infty} (1-\theta)^j\, m^e_{t+j+i} + \sum_{j=0}^{\infty} (1-\theta)^j\, R^e_{t+j+i}$$

$$-\theta^* \sum_{j=0}^{\infty} (1-\theta^*)^j\, m^{*e}_{t+j+i} - \sum_{j=0}^{\infty} (1-\theta^*)^j\, R^{*e}_{t+j+i}$$

and working backwards recursively yields

$$(11) \qquad \tilde{f}^1_t = s^e_{t+1} + \rho + \tilde{\varepsilon}_t = A + \theta \sum_{j=0}^{\infty} (1-\theta)^j m^e_{t+j+i} + (1-\theta)R^e_{t+1}$$

$$-\theta^* \sum_{j=0}^{\infty} (1-\theta^*)^j m^{*e}_{t+j+i} - (1-\theta^*)R^{*e}_{t+1}$$

$$+ \sum_{j=3}^{\infty} \{[(1-\theta)^j - 1]R^e_{t+j-1} - [(1-\theta^*)^j - 1]R^{*e}_{t+j-1}\} + \rho + \tilde{\varepsilon}_t$$

where $R^e_{t+j} = R^{*e}_{t+j}$ for all $j > i$. Expected real income is assumed fixed throughout.

The expected future money supplies enter the relation in precisely the same fashion as they enter the price level equations for both currencies. The sum of the weighted differences in expected real rates summarize the extent and length of the adjustment of the goods markets. These differences can exist because relative goods prices do not adjust within one time period due to underlying adjustment costs. If there were no such costs, the risk adjusted real rates would be equalized through the flow of goods. This constitutes the difference between the monetary approach and the asset approach in this framework. If real rates of returns are never expected to be equalized, the forward rate is not defined in the model; the infinite series of interest rates no longer converges. The economic rationale for this result is that with no ultimate price arbitrage on goods, including payments that accrue to foreign capital owners, there is nothing in the model to fix the exchange rate between the two countries. It is worth noting that even if the real rate of interest is the same in the two countries, changes in that rate will affect exchange rate expectations to the extent that interest elasticities differ between the two countries, as pointed out by Dornbusch (1976).

3. Empirical Results[7]:

In Protopapadakis (1979) I have shown that among various efficient, adaptive-regressive and adaptive expectations specifications, adaptive expectations formed directly on the growth rate of the money supply is the only specification not rejected by the German hyperinflation data. The tests were conducted using domestic price data over the same sample period and within the same money demand/supply framework developed in section three of this paper. They consist of testing the have also shown that the ratio of government bonds to money (B/M) is an important explanatory variable in the domestic price equation and it appears to capture expectations about the short term monetary policy of the central bank. Accordingly, the analysis will be done using the adaptive expectations formulation and the (B/M) variable from the demand for money equations will be retained in the exchange rate equations.

Let $\mu_t = m_t - m_{t-1}$. From adaptive expectations the expected one period growth rate of the money supply is given by:

$$\text{(12a)} \qquad \mu_t^e = \mu_{t+j}^e = \frac{\beta}{1-(1-\beta)L}\mu_t$$

where L is the lag operator. This implies that

$$\text{(12b)} \qquad m_{t+j}^e = m_t + j\mu_t^e$$

Substituting this in (11)

$$\text{(13a)} \qquad \tilde{f}_t^1 = A + m_t + \frac{(1+\alpha)\beta}{1-(1-\beta)L}\mu_t + \phi(\Gamma)R_t^e - \phi^*(\Gamma)R_{t+1}^{*e} + \sum_{j=3}^{\infty}(R_{t+j-1}^{*e} - R_{t+j-1}^e) - p_{t+1}^{*e} + \delta(B/M)_{t+1}^e + \zeta(L)\tilde{\varepsilon}_t$$

where $\phi(\Gamma)$, $\phi^*(\Gamma)$ represent polynomial lead operators, p_{t+1}^{*e} summarizes the money demand variables for the foreign country and $\zeta(L)$ is the structure of the error term. Assuming the real rate of return adjusts within one period ($R_{t+1}^e = R_{t+1}^{*e}$) reduces the equation to:

$$\text{(13b)} \qquad \tilde{f}_t^1 = A_f + m_t + \frac{(1+\alpha)\beta}{1-(1-\beta)L}\mu_t + \delta(B/M)_{t+1}^e - p_{t+1}^{*e} + \zeta(L)\tilde{u}_t^f$$

while the corresponding spot rate equation becomes

$$(14) \qquad \tilde{s}_t = A_s + m_t + \frac{\alpha\beta}{1-(1-\beta)L}\,\mu_t + \frac{\alpha}{1+\alpha}\,R^e_t - \frac{\alpha^*}{1+\alpha^*}\,R^{*e}_t$$

$$+\ \delta(B/M)_t - p^{*e}_t + \zeta(L)\tilde{u}^s_t$$

The implication of the exchange rate theory developed in the previous section is that the price of money, spot and forward rates are generated by the determinants of the demand and supply of money and other assets and that the forward rate is the best predictor of the spot rate, given current information. This implies that estimates of α, β and δ from the spot and forward rate equations will not be statistically different. The efficiency hypothesis further implies that the equation that determines the spot rate should also predict the forward rate, given currently available information. This means that estimates of the remaining coefficients from the two equations should be statistically indistinguishable.

Table 3 contains the results of likelihood ratio tests of the constraints implied by the above hypothesis.[8] The restriction that α, β, δ, b and ρ are the same in the two equations cannot be rejected at the 99% confidence level. This implies that both the forward and spot rate respond to monetary variables in an identical manner. Testing the restriction on b and ρ separately give the same results. These results are strong support for the monetary theory of exchange rates as well as the hypothesis that exchange markets were efficient during this period. Since the coefficients are the same in the two equations, the conclusion is that the forward rate is an ex-ante unbiased and efficient predictor of the spot rate. Since the constant terms are fixed biases exist as well. The reported tests are severe tests of the theory not only because they are joint tests of the monetary theory, the efficiency hypothesis and the expectations specification but also because any additional specification errors and omitted variables that have differential impacts on the two rates will make rejection more likely.

As discussed in section, the distinction between the monetary and the asset approach is represented by the currently expected real rate of return that appears only in the spot rate equation. Unfortunately, since interest rate data are not available, it is not possible to test the distinction directly. However, if the expected real rate of return (R_t^e) is serially correlated, its absence will result in a different autocorrelation structures in the two equations. The results show that the estimates of the autoregressive coefficient (ρ) are indistinguishable from one another and from zero. Furthermore, if R_t^e is correlated with any of the independent variables in the spot rate equation the tests would be biased towards rejection. I can only conclude that it is not possible to detect evidence favoring the asset versus the monetary approach from the available information.

The conclusion that the forward markets are efficient seems to be in conflict with the evidence in section two where I show that the forward rate systematically tends to underpredict the spot rate while the latter is expected to rise. The evidence above suggests that the ex-post underprediction is caused by lagging monetary growth expectations rather than inefficiencies specific to the exchange market. The phenomenon occurs because adaptive expectations tend to underpredict the money supply during periods of accelerating growth. As the current money supply exceeds forecast levels, the spot rate as well as the price level rise above their expected level. Thus the ex-post forecasts appear inefficient.

An additional feature of the results in Table 3, is that the foreign price level in period t enters both the spot and forward rate equations. This is consistent only if economic actors have static expectations about the foreign price level. If it is instead assumed that their expectations of the future foreign price level are correct, the foreign price level realized in period t+1 should enter in the forward rate equation. This specification does not perform well. The coefficient in the forward rate equation is not significantly different from zero, the mean square error of the regression increases and the regression residuals are autocorrelated.[9] A more complete treatment would involve specifying the determinants of the foreign price level explicitly and performing all the tests for both countries but is beyond the scope of this paper. Regardless whether the foreign price level at t or t+1 is used, the hypothesis that b is the same across equations cannot be rejected. However, the monetary approach requires not only that all the parameters in the spot and forward market equations be the same but also that the foreign price level coefficient be unity. That restriction is rejected at the 99% level. While recognizing that the high estimates of the coefficient may de due to specification error, the foreign price level will be retained in the subsequent sections.

Since the current value of the bonds to money ratio (B/M) is used in both equations, the additional implication of δ being the same across equations is that expectations with respect to this ratio are static so that economic actors expect policies implied by the current value of the variable to continue. Additional lagged or future values of (B/M) do not carry significant coefficients.

5. Additional Tests of the Monetary Theory:

The exchange rate is the relative price of two monies. The monetary approach asserts that the exchange rate is determined only by the ratio of the purchasing power of the two monies. The assymetry introduced in this way is that, unlike relative prices of goods, there are no special relative price variables that affect exchange rates. The theoretical debate over the determinants of exchange rates has not been resolved. Alternative theories deny this assymetry and propose variables that will affect the relative price of monies. Income determination models propose the trade surplus as a key variable affecting exchange rates.[10] According to this view, an increase in the real trade surplus of a country increases the demand for domestic currency by foreigners, causing the exchange rate to rise and the terms of trade to deteriorate. This scenario is in direct conflict with the monetary approach which specifically denies the trade surplus as a relevant variable.

Idiosyncratic models involving the specific circumstances surrounding the German hyperinflation have been proposed as well. A favorite hypothesis is that the reparations payments Germany was obligated to make caused the rapid depreciation of the Reichsmark which in turn precipitated the domestic inflation. The monetary approach denies that such a variable is relevant. This hypothesis is tested by including cash reparation payments, as well as bonds issued to foreigners in lieu of cash reparations, in the exchange market regressions.

During the early part of 1923, before the final collapse of the value of the currency, the Reichsbank undertook foreign exchange operations to halt the decline of the Reichsmark. It is generally thought that sufficiently large central bank support of the currency will affect its external value. To capture this effect, the reported amount of official support for that period is included in the regressions.

Liquidity creation, reparation payments and exchange rate support can all be viewed as alternative avenues of central authority intervention in the money markets. Treating the latter two as possible relative price variables acknowledges the possibility that these avenues of intervention work through different channels. Monetary theory, in contrast to the asset approach, asserts that there should be no effects beyond that on velocity and on the money supply.

The results of a simultaneous test of these hypotheses are reported in Table 4 and broadly support the monetary approach of the determination of exchange rates. The coefficient of the trade surplus variable is not different from zero at traditional significance levels; furthermore it has the wrong sign. There is also no evidence to support the notion that reparation payments, whether in cash or bonds, in any way affected the course of exchange rates. The only variable that seems to have an effect is central bank support of the Reichsmark in the exchange markets.

An interesting theoretical question is why the central bank support has any additional effects? There seem to be three alternative possibilities that cannot be distinguished based on these data. One is that official currency support modifies short term expectations. Ceteris paribus, such support may signal an increasing resolve to reduce monetary expansion which will lead economic agents to modify their expectations of future inflation, affecting the spot and forward rates. The second is that it affects the exchange rate because of finite short run supply elasticities for speculative funds. If the central bank wishes to support the exchange rate, taking a position opposite the bank is a poor short run bet. This knowledge on the part of speculators may be suffi-cient to have a measurable effect on the exchange rates. The third possibility has been discussed in the asset approach literature.[11] In contrast to open market operations, official currency support results in a reduction of the domestic money supply and an increase in the foreign money supply. Depending on how and where reserves are held, the domestic and foreign bond to money ratio as well as the ratio of the two monies may be altered. If bonds are even partially net wealth, currency support will alter the equilibrium price levels, exchange rates and rates of return. Sterilization operations of the foreign central bank alone cannot restore the original equilibrium.

The magnitude of the effect is of some interest. The amount of support during the period averaged approximately 20 percent of the issue of new money, a relatively modest amount. While a 1.0 percentage point decrease in the expected growth rate of the money supply will caue the spot rate to decrease by 4.96 percent, the same decrease resulting from exchange rate support will cause the exchange rate to decrease by approximately 20.3 percent while intervention is taking place.[12] Once support is withdrawn, the exchange rate returns to its original unsupported level.

6. Joint Estimation of Sector Prices and Exchange Rates:

The conclusions of the previous section can be further tested by using domestic goods market data. If the monetary theory of exchange rates is relevant not only should the forward and spot rates obey the same time series process but the elasticity and adjustment coefficient estimates obtained from the exchange markets should be the same as those obtained from the domestic goods markets. Recent evidence presented by Frenkel (1976) shows statistically significant variations among estimates of these parameters when different price indices are used. This may be due to biases associated with the indices themselves. In principle, it is possible to circumvent this bias by using price series for each individual good and specifying demand and supply variables that affect the relative prices of goods. The demand and supply functions for the j'th good are given by:

(15a) $$\tilde{D}_j = D_j(P_j/P,\ y,\ a,\ \vec{\rho};\ \tilde{T}^d)$$

(15b) $$\tilde{S}_j = S_j(P_j/P,\ w,\ \vec{\rho},\ \vec{R};\ \tilde{T}^s)$$

(15c) $$\tilde{D}_j = \tilde{S}_j \qquad 1 \leq j \leq n$$

for n goods where ρ_j is the price of the j'th good, 1/P is the price of money, y, a and w are income, wealth and wages in real terms; $\vec{R}$ and $\vec{\rho}$ are respectively vectors of interest rates and relative prices for all but the j'th commodity while T^d, T^s are demand and supply pormanteau variables, including stochastic elements. Such a system of equations has in principle a reduced form solution for each relative price in terms of the exogenous variables; the coefficients will combine demand and supply effects.

Take logarithms and write the reduced form relation for the j'th good:

$$(16) \qquad \tilde{p}_j - \tilde{p} = \ell_j(y,\ a,\ w,\ \vec{R};\ \tilde{T})$$

Combining this with equation (6) yields an expression for the money price of each good composed of the underlying price trend that depends on monetary variables and departures from that trend due to relative price changes

$$(17) \qquad \tilde{p}_j = \ell_j(y,\ a,\ w,\ \vec{R};\ T) + \theta \sum_{j=0}^{\infty} (1-\theta)^j [m^e_{t+j} - y^e_{t+j}] + \sum_{J=0}^{\infty} (1-\theta)^j R^e_{t+j} + \tilde{u}_t$$

Sector price indices are available for food cost, heating cost, clothing cost and housing cost for Germany during this period. The housing cost index is excluded here because of effective rent controls imposed by the government. Goods prices are thus summarized in three sectors whose relative prices are free to vary. These equations are then jointly estimated with the exchange market equations.

The hypothesis examined is that the same money demand function and expectations mechanism that drive the sector prices also drive the spot and forward rates. Sector prices are written as a function of the demand and supply of money with parameters α_1, β_1. The forward and spot rates are written as a function of the demand and supply of money as well, but with parameters α_2, β_2; all the real variables that may affect relative prices are included in each equation.

directly by testing the restriction that $\alpha_1 = \alpha_2$ and $\beta_1 = \beta_2$. Results are reported in table 5.

The hypothesis that the same demand for money function drives exchange rates and domestic goods prices cannot be rejected at any reasonable level of significance. To assess this conclusion, one needs to know the power of the test. Table 6 reports some simulation results aimed at estimating the power. Using the variance-covariance matrix from table 5, enough residuals were generated for one hundred replications. The five dependent variables (31 observations for each replication) were computed using the money supply and growth rate data. All independent variables whose coefficients are not restricted were eliminated to reduce the computational burden. For each value of the parameters, the value of twice the log likelihood ratio, $2(L_2-L_1)$, needed to test the null hypothesis ($\alpha_1=\alpha_2$, $\beta_1= \beta_2$) is computed. The table reports the mean and range of the values obtained, along with the acceptance rate of the null hypothesis at different confidence levels. The table also reports some results when $\alpha_1-\alpha_2$ and $\beta_2-\beta_1$ are varied simultaneously.

The value of $2(L_2-L_1)$ for the test of the null hypothesis ($\alpha_1=\alpha_2$ and $\beta_1=\beta_2$) in table 5 is 0.11. Given the simulation results, the approximate probability that this value would be obtained if α_2 differed from α_1 by 6 percent (while $\beta_1=\beta_2$) is less than one in a hundred. Alternatively the probability that this value of the likelihood statistic would be obtained if β_2 different from β_1 by 5 percent (while $\alpha_1=\alpha_2$) is also less than one in a hundred.

These results indicate that the likelihood test used is quite powerful and lend strong support to the notion of a stable demand for money function as well as to the monetary theory of exchange rate determination. The estimates have relatively high precision because information from several markets is being used. The estimate of (α) is surprisingly close to Cagan's(1956), but the estimate of the adjustment coefficient (β) is considerably smaller[13]. The estimates in table 5 also imply that the process is dynamically stable ($\alpha\beta<1$) in the sense that the hyperinflation was not self-generating. The assertion of Sargent and Wallace (1973) that if adaptive expectations are rational $\text{plim}\ \hat{\alpha} = \frac{1-\beta}{\hat{\beta}}$, is tested by imposing that restriction ($\alpha\beta = 1-\beta$) on the model. The restriction fails at any reasonable significance level. This can be taken as evidence that the estimating procedures used here are not inconsistent.

The bonds to money ratio (B/M) is a significant determinant of prices and exchange rates. The proposition that this coefficient is the same across all regressions is also tested. This proposition is not supported by the evidence. If indeed the (B/M) ratio is an expectations variable then the conclusion is that it is perceived differently in the goods than in the exchange markets. This is not implausible since domestic markets are primarily influenced by domestic economic actors, while the exchange markets are influenced by both domestic and foreign actors.

The exchange rates seem to be more sensitive to this variable than sector prices. Since the (B/M) ratio has no pronounced trend over the sample period, the larger coefficient in the exchange market equations contributes to the apparent volatility of the exchange rates.

Finally, the proposition that the autoregressive coefficient is the same across all markets is examined. This proportion fails as well. It could be that characterizing the error term of the regression as a first order autoregressive reveal similarities not captured by this naive assumption. On the other hand, if the AR1 assumption is accepted the finding once again implies that the external price of the currency is more volatile than its internal price. The variance of the innovations in the spot and forward markets is statistically indistinguishable from each other while among the goods markets the ratio of the variances does not exceed three. The variance of the exchange market innovations however is somewhere between 5.0 and 14.0 times higher than those of the goods markets. An additional element of volatility is introduced by the fact that the autoregressive coefficient in the exchange market is negative and significantly different from zero. This means that the ratio of the variance of the exchange market residuals is between 6.6 and 19.2 times any of those observed in the goods markets. Furthermore, the negative autocorrelation found in the exchange markets gives the residual series a characteristic "choppy" appearance, enhancing the impression of exchange rate volatility.

5. Conclusion:

The methodology used in this paper is to derive various restrictions implied by the monetary theory of exchange rates and test whether they are upheld by the data. The main findings on the whole support the monetary approach. The demand for and supply of money appear to drive both goods prices and exchange rates in the same way. In addition, the forward rate appears to be generated by the identical process that generates the spot rate.

However, it is also clear that the processes driving prices and exchange rates are not identical in every respect. The differences coefficient can perhaps be rationalized in terms of heterogenous expectations among different groups of economic actors and in terms of adjustment lags.

Some comparison between the monetary approach, the income-expenditure approach and the asset approach are also presented. The trade balance, an important variable in the income-expenditure approach, as well as reparations payments have no direct effect on exchange rates. Due to lack of interest rate data, a direct comparison between the monetary approach and asset approach is not possible. However, if the asset approach is the correct model then the spot market equation in the paper is misspecified, since it omits the real interest rate variable. There is no trace of the usual problems encountered with omitted variables. This is weak evidence favoring the monetary approach over the asset approach.

FOOTNOTES:

[1]In the regression $y_t = b_o + \beta_1 x_t + \tilde{u}_t$, $b_o = \beta_o - \sigma^2_{u/2}$, theory predicts $\beta_o = 0$. The inference problem is: Given $\hat{b}_o$, $\hat{\sigma}^2_u$ estimates of the parameters what is the probability that $\hat{b}_o$ will be observed if $\beta_o = 0$. The sum of a normal (β_o) and a χ^2, (σ^2_u) distribution is not readily available. However, for 30 df the χ^2 distribution can be approximated by the normal distribution and since the estimates of β_1 and b_o are independent, the inference problem is simplified.

$$\hat{\beta}_o \stackrel{\sim}{\sim} N\ [\beta/\sigma_\beta = (\frac{\sigma^2(\hat{b}_o)}{N} + \frac{\sigma^2(\hat{\sigma})}{N})^{\frac{1}{2}}]$$

$$\hat{\sigma}^2(b_o) = 0.089; \qquad \hat{\sigma}^2(\sigma) = 0.212$$

and $\sigma^2_{\beta_o} = .096$ so that the t-statistic for $\hat{\beta}_o$ is 0.48. It is possible to formulate a precise maximum likelihood estimation procedure and test the restriction directly.

[2]The sample here excludes the month of August which is included in Frenkel and probably accounts for the difference. His results are $b_o = -0.46$ (0.24), $b_1 = 1.09$ (0.03). The exchange market data are taken from Einzig (1937) while all the other data are from "Zahlen Zur Geldentwertung in Deutschland 1914 bis 1923," (1925), "Germany's Economy, Currency and Finance," (1924) and Dulles (1929).

[3]The weekly $\ln S_t - \ln F^1_{t-1}$ series is constructed by matching each end-of-the-week spot rate to a forward rate that most closely approximates the one-month interval. No interpolation is attempted. This procedure explains why the lag-4 autocorrelation although not statistically significant is suspiciously large.

Until November 1921, the forward rates were quoted, like futures contracts, to the end of the calendar month. After that they were for one month intervals.

[4]The results from the monthly data are Q(12) = 6.83; Q(24) = 14.00. Results from the weekly data taken at 4 week intervals are Q(12) = 9.52; Q(24) = 18.8, far below reasonable critical levels.

[5]In contrast, Metzler (1960) describes a full equilibrium model where capital flows are a function of the difference in real returns.

[6]Black (1973), H. Grubel (1966), and H. Stoll (1968) in contrast describe models where IRPT does not hold.

[7]All the empirical estimations in this and the subsequent sections were performed using a FIML estimation package developed by Dr. Clifford Wymer of the IMF.

[8]The lagged polynomial on the error term $\zeta(L)$ has been approximated by $\frac{1}{1-\rho L}$ in the empirical tests.

[9]The estimated values of the coefficients are:

	Unconstrained	α, β, δ Constrained	α, β, δ, b constrained
forward rate	.1693 (0.45)	-.1124 (0.31)	.7036 (2.02)
spot rate	.6400 (2.27)	.6084 (2.19)	

[10]See Mundell (1968), Frenkel (1976).

[11]Dooley and Isard (1977), Girton and Henderson (1976).

[12]This figure is calculated as follows:

$$\frac{\Delta P}{P} = \alpha \Delta \mu_t^e + d\Delta INT$$

where $\alpha = 4.96$, $d = -0.0083$

A 1 percentage point decrease in μ_t^e means a decrease in new real cash balances issued of 13.4, 19.5, 22.4 million Goldmarks for March, April and May, respectively. This corresponds to a decrease in the spot rate of 11.12 percent, 16.18 percent, 18.59 percent, respectively due to the official support and an <u>additional</u> 4.96 percent decrease due to the μ_t^e term.

[13]Cagan's estimates are $\alpha = 5.46$, $\beta = 0.20$.

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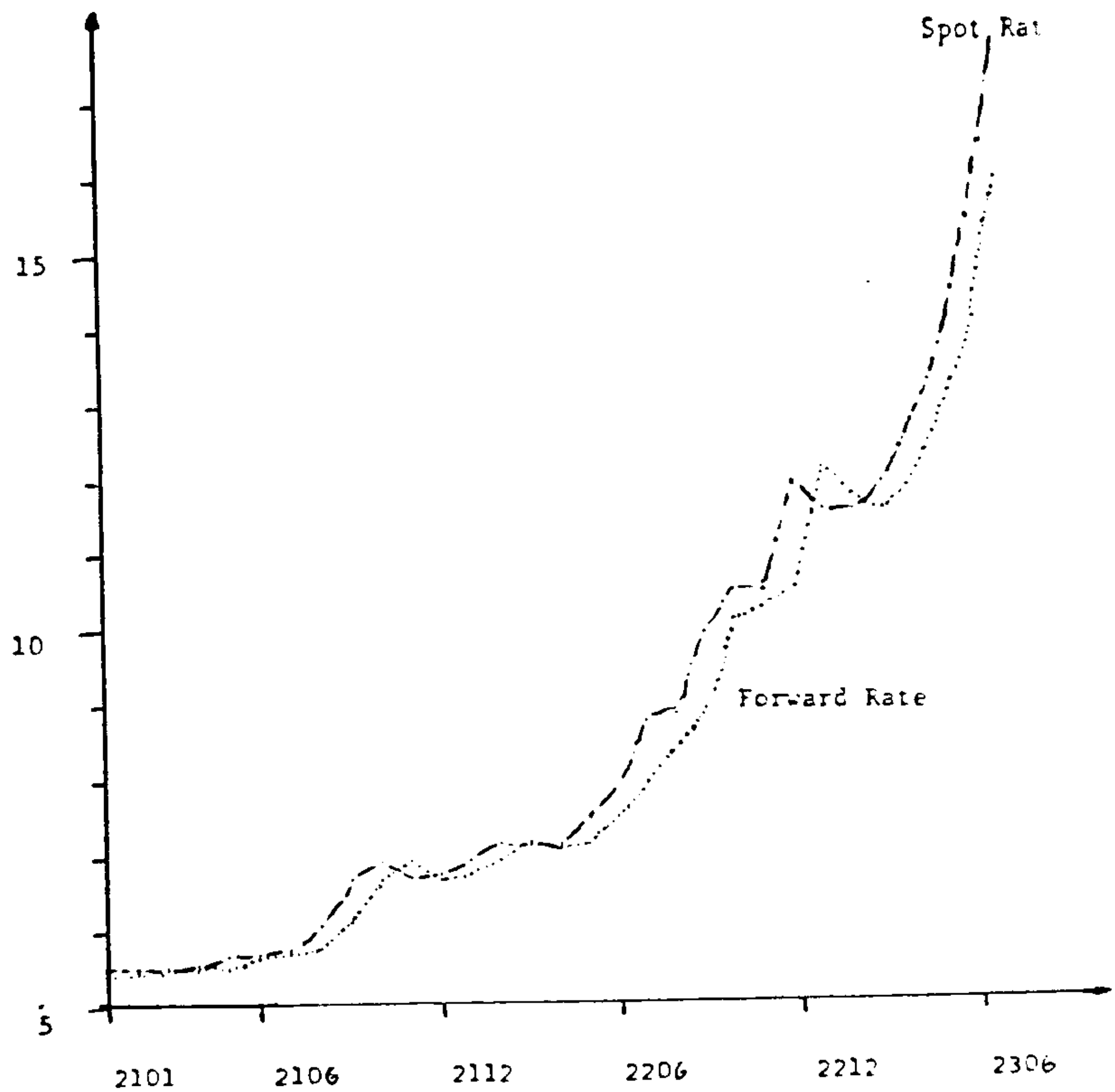

Figure 1. Spot and Forward rates. Variables are in logarithms.

TABLE 1

TIME SERIES MODEL FOR THE EX-POST FORWARD RATE PREDICTION ERROR

WEEKLY DATA

Autocorrelations 1	2	3	4	5	6	7	8	S.E.	R^2	Q(12)	Skewness	Kurtosis
.79	.53	.26	-.04	-.14	-.17	-.16	-.08	.10	.000	129.6	.744	3.43
.12	.05	.11	-.01	-.13	-.10	-.06	.04	.10	.746	7.8	-.015	5.42
.01	.06	-.05	-.06	-.08	-.08	.04	.04	.10	.754	4.6	-.266	5.49
-.02	.03	.01	-.10	-.03	-.05	-.09	.03	.10	.756	3.8	-.559	5.84

Coefficient Estimates[1]

LS:	(0,3)	(0,4)	(1,3)
	θ_1 = -.935** (14.30)	θ_1 = -1.037** (10.83)	ϕ_1 = .376** (3.06)
	θ_2 = -.821** (10.13)	θ_2 = -.886** (7.67)	θ_1 = -.684** (6.95)
	θ_3 = -.775** (11.09)	θ_3 = -.895** (7.85)	θ_2 = -.551** (5.42)
		θ_4 = -.175 (1.64)	θ_3 = -.687** (8.25)

model (0,3) versus (0,4) = 3.38
model (0,3) versus (1,3) = 4.26*

at the 5% level
at the 1% level

[1] ϕ_i refers to the i'th autoregressive coefficients.

θ_i refers to the i'th moving average coefficient.

TABLE 2[a]

TESTS OF PREDICTION BIAS IN THE FORWARD RATE

(1) $$\ln \tilde{S}_t = b_o - \frac{\sigma_u^2}{2} + b_1 \ln F_{t-1} + \tilde{u}_t$$

(2) $$\ln \tilde{S}_t = b_o - \frac{\sigma_u^2}{2} + b_o'\Delta + b_1 \ln F_{t-1} + \tilde{u}_t$$

(3) $$\ln \tilde{S}_t = b_o - \frac{\sigma_u^2}{2} + b_o'\Delta + (b_1 + b_1'\Delta) \ln F_{t-1} + \tilde{u}_t$$ [c,e]

(4) $$\ln \tilde{S}_t = b_o - \frac{\sigma_u^2}{2} + (b_1 + b_1'\Delta) \ln F_{t-1} + \tilde{u}_t$$ [d,e]

Equation	$b_o - \frac{\sigma_u^2}{2}$	$b_o'\Delta$	b_1	$b_1'\Delta$	Statistics
(1)	-.150* - .106 = -.256* (.030)		1.068* (0.034)		R^2 = .974; Q(12) = 7.40/12.00; DW = 2.03
(2)	-.923* - .059 = -.482* (.271)	.747* (.159)	1.085* (.0026)		R^2 = .986 [b]; Q(12) = 7.40/12.00; DW = 2.44
(3)	.178 - .045 = .133 (.451)	-.655 (.501)	.961* (.048)	.159* (.055)	R^2 = .990; Q(12) = 7.44/12.00; DW = 2.39
(4)	-.351 - .046 = -.397* (.199)		1.016* (0.024)	0.090* (0.015)	R^2 = .989; Q(12) = 7.44/12.00; DW = 2.48

Theoretical Predictions

$b_o = 0.00$

$b_1 = 1.00$

$b_o' = b_1' = 0.00$

F - Tests Between:

1&2	21.43*
1&3	19.20*
1&4	34.09*
2&3	9.44*
3&4	1.90

*Implies statistical significance at the 5% level. Numbers in parenthesis are standard errors.

[a] Regression (1) is identical to (2b) in the text.

[b] Q(12) statistic is reported as a fraction. The actual value is the numerator while the expected value is the denominator.

[c] The constant terms here are both indistinguishable from zero.

[d] The t-statistic computed as described in Footnote 4 is 1.92 and b_o is not significantly different from zero at the 95% confidence interval.

[e] In equations (3) and (4) b_1 is not significantly different from unity.

TABLE 3

JOINT ESTIMATION IN THE EXCHANGE MARKETS [a]

$$(1a)\quad \ln\tilde{F}^1_t = \ln M_t + \frac{(1+\alpha_1)\beta_1}{1-(1-\beta_1)L}\mu_t + \delta_1(B/M)_t - b_1(BWPI)_t + \frac{1}{1-\rho_1 L}\tilde{u}^f_t$$

$$(1b)\quad \ln\tilde{S}_t = \ln M_t + \frac{\alpha_2\beta_2}{1-(1-\beta_2)L}\mu_t + \delta_2(B/M)_t - b_2(BWPI)_t + \frac{1}{1-\rho_2 L}\tilde{u}^s_t$$

$\alpha_1 = \alpha_2$	=	2.5487	(2.93) [b]
$\beta_1 = \beta_2$	=	0.0833	(5.54)
$\delta_1 = \delta_2$	=	-1.3309	(6.96)
$b_1 = b_2$	=	3.0604	(6.26)
$\rho_1 = \rho_2$	=	0.1113	(0.74)

<u>Forward Rate</u>[c]

Constant	=	-17.8588 (5.06)
MSE	=	0.119538
R^2	=	0.9854
Q(12)	=	15.05
D.W.	=	1.38

<u>Spot Rate</u>

Constant	=	-17.8857 (5.07)
MSE	=	0.092915
R^2	=	0.9879
Q(12)	=	14.83
D.W.	=	1.45

<u>Hypothesis Testing</u>

Restriction Tested	χ^2	DF
$\alpha_1 = \alpha_2,\ \beta_1 = \beta_2,\ \delta_1 = \delta_2$	9.40	3
$\alpha_1 = \alpha_2,\ \beta_1 = \beta_2,\ \delta_1 = \delta_2,\ b_1 = b_2$	9.56	4
$\alpha_1 = \alpha_2,\ \beta_1 = \beta_2,\ \delta_1 = \delta_2,\ b_1 = b_2,\ \rho_1 = \rho_2$	15.56	5

TABLE 3 - Continued

CRITICAL VALUES

	X^2 (.025)	X^2 (.01)	X^2 (.005)	X^2 (.001)
1DF	5.02	6.64	7.88	10.83
2DF	7.38	9.21	10.60	13.82
3DF	9.35	11.34	12.84	16.27
4DF	11.14	13.28	14.86	18.47
5DF	12.83	15.09	16.75	20.52

a. The regression results reported are for the case where α,β,δ,b and ρ are constrained to be the same for the two equations.

b. Only the results for the constrained regression are shown here for brevity.

c. The statistics provided are for each separate regression.

TABLE 4

ADDITIONAL VARIABLES FOR THE EXCHANGE MARKET [a,b]

(1a)

$$\ln \tilde{F}_t^1 = \ln M_t + \frac{(1+\alpha)\beta}{1-(1-\beta)L} \mu_t + \delta(B/M)_t - b(BWPI)_t + c(REP)_t$$

$$+ d(RBND)_t + e(TS)_t + g(INTV)_t + \frac{1}{1-\rho L} \tilde{u}_t^f$$

(1b)

$$\ln S_t = \ln M_t + \frac{\alpha\beta}{1-(1-\beta)L} \mu_t + \delta(B/M)_t - b(BWPI)_t + C(REP)_t$$

$$+ d(RBND)_t + e(TS)_t + g(INTV)_t + \frac{1}{1-\rho L} \tilde{u}_t^s$$

	Constrained	Unconstrained
α = 5.3028 (4.91)	c = -0.0002 (0.23)	-0.0004 (0.42) -0.0003 (0.38)
β = 0.0828 (5.58)		
δ = -0.9228 (3.87)	d = 0.0001 (0.55)	-0.0001 (0.17) -0.0001 (0.27)
b = 2.7183 (6.16)		
ρ = 0.1044 (0.67)	e = -0.0008 (1.81)	-0.0001 (0.13) -0.0002 (0.40)
	g = -0.0052 (3.46)	-0.0084 (3.68) -0.0077 (3.86)

TABLE 4 - continued

Forward Market			Spot Market		
Constant	=	-15.6063 (4.67)	Constant	=	-15.6331 (4.67)
MSE	=	.091658	MSE	=	.067932
R^2	=	.9888	R^2	=	.9912
Q(12)	=	15.84	Q(12)	=	16.76
D.W.	=	1.64	D.W.	=	1.74

χ^2 = 4.50 (4DF)[c]

Notes:

[a]BWPI represents the British Wholesale Price Index

REP represents the actual reparation payments made by Germany in real terms.

RBND represents bonds issued to foreign governments in liew of cash payments in real terms. These were short term bonds and were all redeemed within the sample period.

TS represents the real trade surplus in terms of value.

INTV represents intervention of the Reichsbank in the exchange market in real terms.

[b]The coefficients of the above variables are displayed separately below. The column on the left contains the coefficient estimates when the coefficients are constrained across the two equations, while the column on the right contains the unconstrained estimates. The first row in each case is for the forward market equation. T-values are in parentheses.

[c]The χ^2 - statistic tests the restriction that c,d,e, and g are the same across equations for each variable.

Critical Values are:

χ^2_2 (.50) = 3.36
χ^2 (.25) = 5.39

TABLE 5

THE GOODS AND FOREIGN EXCHANGE MARKETS: FINAL ESTIMATES [a,b]

$$\ln\tilde{P}^j_t = \ln M_t + \frac{\alpha\beta}{1-(1-\beta)L}\mu_t + \delta_1\left(\frac{B}{M}\right)_t + c^j_1\, UNT_t + c^j_2\, UNT_{t-1} + c^j_3\, UNS_t$$

$$+ c^j_4\, UNS_{t-1} + c^j_5\, STR_t + c^j_6\, WR_t + c^j_7\, WR_{t-1} + \frac{1}{1-\rho_1 L}\tilde{u}^j_t$$

$$j = 1,3$$

$$\ln\tilde{F}^1_t = \ln M_t + \frac{(1+\alpha)\beta}{1-(1-\beta)L}\mu_t + \delta_2\left(\frac{B}{M}\right)_t + d\ INTV_t - b\ BWPI_t + \frac{1}{1-\rho_2 L}\tilde{u}^f_t$$

$$\ln\tilde{S}_t = \ln M_t + \frac{\alpha\beta}{1-(1-\beta)L}\mu_t + \delta_2\left(\frac{B}{M}\right)_t + d\ INTV_t - b\ BWPI_t + \frac{1}{1-\rho_2 L}\tilde{u}^s_t$$

α =	4.9677	(10.34)	b =	2.4092	(13.26)
β =	0.0777	(9.94)	d =	-0.0083	(10.08)
δ_1 =	-0.4782	(6.41)	δ_2 =	-1.3269	(16.37)
ρ_1 =	0.1062	(1.52)	ρ_2 =	-0.3479	(4.12)

$\alpha\beta$ = 0.3861 (11.31)

	c_1	c_2	c_3	c_4	c_5	c_6	c_7
ln FCI	0.0012	-0.0353	-0.0192	0.0045	-0.1951	-0.3702	-0.1998
	(0.07)	(2.08)	(3.17)	(0.86)	(4.91)	(4.59)	(2.57)
ln HECI	-0.0034	-0.0690	0.0155	-0.0048	-0.2273	-0.4204	-0.2138
	(0.14)	(2.95)	(1.84)	(0.67)	(4.14)	(3.76)	(1.93)
ln CCI	0.0044	-0.0110	-0.0213	-0.0077	-0.2781	-0.1012	-0.1930
	(0.17)	(0.42)	(2.31)	(0.49)	(5.14)	(0.80)	(1.57)

TABLE 5 - continued

Summary Statistics:

Equation	Constant	MSE	R^2	Q(12)	D.W.
ln FCI	-0.0340 (0.37)	0.007096	.9987	10.92	2.07
ln HECI	-0.0034 (0.04)	0.005951	.9990	13.02	2.47
ln CCI	-0.5086 (3.70)	0.017294	.9969	9.41	1.40
ln F	-22.4631 (11.60)	0.101313	.9876	12.91	1.44
ln S	-22.5012 (11.61)	0.078110	.9898	13.54	1.47

Hypothesis Testing:[c]

Restriction Tested	$2(L_2-L_1)-\chi^2$ distributed	DF
$\alpha_1=\alpha_2, \beta_1=\beta_2$	0.11	2
$\delta_1=\delta_2$	34.53	1
$\rho_1=\rho_2$	16.28	1
$\alpha = \frac{1-\beta}{\beta}$	50.58	1

Ratio of Residuals Variances:[d]

	HECI	FCI	CCI	S	F
HECI	1	1.19 (1.19)	2.91 (2.91)	13.13 (14.76)	17.02 (19.95)
FCI	-	1	2.44 (2.44)	11.01 (12.38)	14.28 (16.06)
CCI	-	-	1	4.52 (5.08)	5.86 (6.59)
S	-	-	-	1	1.30 (1.30)
F	-	-	-	-	1

TABLE 5 - Continued

P^1	=	Food cost index.
P^2	=	Heating cost index.
P^3	=	Clothing cost index.
B/M	=	Ratio of total outstanding government bonds to money.
UNT	=	Unemployment level of full time workers (Union).
UNS	=	Unemployment level of short time workers (Union).
STR	=	Stock Price index in real terms.
WR	=	Real wage rate.
INTV	=	Central Bank intervention in real terms.
BWPI	=	British wholesale price index.

Notes:

a. Below are the regression coefficients and t-statistics for the version of the model displayed. α and β are constrained to one value across all equations, δ and ρ are constrained to one value across the P^J equations and another across the exchange market equations while b and d are constrained to one value across the exchange market equations. The coefficient estimates of the rejected models are not reported.

b. The sum of squares for the regressions were 5.563527, 6.222480, 5.497080, 8.181825, 7.687901 respectively.

c. For the relevant values of the χ^2-statistic see Table 3.

d. The table shows the ratio of the innovation variances $(\tilde{u}_t)$ of each equation. Thus,

$$\frac{VAR(\tilde{u}_f)}{VAR(\tilde{u}_s)} = 1.30.$$

The numbers in parentheses refer to the ratio of the variances of the error term of each regression which is,

$$VAR(\tilde{z}) = \frac{1}{1-\rho^2} VAR(\tilde{u}).$$

All these ratios have an F(30,30) distribution; relevant values are: F(.05) = 1.84, F(.025) = 2.07, F(.01) = 2.39

TABLE 6

POWER OF THE LIKELIHOOD RATIO TEST

Fixed Values:

$\beta_1 = 0.08$

$\alpha_1 = \alpha_2 = 4.97$

Null Hypothesis (H_o)

$\alpha_1 = \alpha_2$, $\beta_1 = \beta_2$

$\beta_2-\beta_1$	% Dev.	Mean	Range	% of time H_o is accepted at 95%	99%	99.9%
0.0000	0.0	2.10	0.05 - 7.70	95	100	100
0.0125	14.5	13.20	1.97 - 28.22	16	31	52
-0.0125	-17.0	14.68	3.59 - 32.53	9	18	49
0.0250	27.2	35.89	17.85 - 55.58	0	0	0

Fixed Values:

$\alpha_1 = 4.97$

$\beta_1 = \beta_2 = 0.08$

Null Hypothesis (H_o)

$\alpha_1 = \alpha_2$, $\beta_1 = \beta_2$

$\alpha_2-\alpha_1$	% Dev.	Mean	Range	% of time H_o is accepted at 95%	99%	99.9%
0.00	0.0	2.10	0.05 - 7.70	95	100	100
0.30	5.9	4.80	0.12 - 17.50	61	89	99
-0.50	-10.6	10.28	1.46 - 26.15	23	48	77
1.00	18.3	27.29	12.69 - 47.84	0	0	4

NOTES

The table summarizes the results of a limited simulation study to ascertain the power of the test conducted in table 5.

Residuals were generated using a random number generator. The population variance-covariance matric of the residuals is identical to the one calculated in table 5. 100 sets of five dependent variables (31 observations per set) were computed by using these residuals along with the money supply and its growth rates from the German data used in the rest of the paper. Relative price variables and (B/M) were neglected to reduce the computational burden. Since there are no cross-equation restrictions associated with these variables, this omission is unlikely to change the results.

The table displays the absolute built-in difference ($\beta_2-\beta_1$ and $\alpha_2-\alpha_1$, respectively) as well the % difference $(\beta_2-\beta_1)/\beta_1$, $(\alpha_2-\alpha_1)/\alpha_1$, the mean and range of twice the difference of the log likelihood, $2(L_2-L_1)$ between the constrained an unconstrained regression and the proportion of cases (out of 100) where the null hypothesis is accepted at different confidence levels (95%, 99%, 99.9%).

APPENDIX

I. ADAPTIVE EXPECTATIONS FORMULATION FOR THE FORWARD RATES

(1) <u>Expectations on Money Growth Rates</u>

(A-1) $$f_t = \sum_{j=0}^{\infty} (1-\theta)^j \theta q^e_{t+j+1}$$

(A-2) let $\mu_t \equiv q_t - q_{t-1} \equiv \ln Q_t - \ln Q_{t-1}$

and by adaptive expectations we have

(A-3) $$\mu^e_t = \frac{\beta}{1-(1-\beta)L} \mu_t = \mu^e_{t+j}$$

(A-4a) $$q^e_{t+j+1} = q_{t+1} + j\mu^e_t$$

(A-4b) $$q^e_{t+j+1} = q_t + (j+1) \mu^e_t$$

Substituting into (A-1)

(A-5) $$f_t = \sum_{j=0}^{\infty} (1-\theta)^j \theta[q_t + (j+1) \mu^e_t]$$

(A-6) $$f_t = q_t + (1+\alpha) \mu^e_t$$

(2) Expectations on Inflation Rates

(A-7) $$f_t = q^e_{t+1} + \alpha\pi^e_{t+1}$$

$$\pi^e_{t+j} = \pi^e_t \quad \text{and} \quad q^e_{t+1} = q_t + \mu^e_t$$

(A-8) $$f_t = q_t + \mu^e_t + \alpha\pi^e_t$$

μ^e_t can be inferred from the money demand equation and π^e_t. The required assumption is consistency though not efficiency of forecasts.

Using the demand for money equation we write:

(A-9a) $$p_t = q_t + \alpha\pi_t^e$$

(A-9b) $$\pi_t = \mu_t + \frac{\alpha(1-L)\beta}{1-(1-\beta)L}\pi_t$$

(A-9c) $$\mu_t = [1 - \frac{\alpha\beta(1-L)}{1-(1-\beta)L}]\ \pi_t$$

(A-10) $$\mu_t^e = [1 - \frac{\alpha\beta(1-L)}{1-(1-\beta)L}]\ \pi_t^e$$

Substitute (A-10) in (A-8) to get:

(A-11) $$f_t = q_t + [1 + \alpha - \frac{\alpha\beta(1-L)}{1-(1-\beta)L}]\pi_t^e$$

(A-12) $$f_t = q_t + \frac{(1+\alpha)\beta}{1-(1-\beta)L}\ \pi_t - \frac{\alpha\beta^2(1-L)}{(1-(1-\beta)L)^2}\ \pi_t$$

II. EFFICIENT EXPECTATIONS FORMULATION FOR THE FORWARD RATES

(1) Expectations on Money Supply

$$f_t = \sum_{j=0}^{\infty} (1-\theta)^j\ \theta\ m_{t+j+1}^e$$

All m_{t+j}^e's are exogenous.

(2) Expectations on Prices

(A-13a) $$p_t = \frac{\theta}{\gamma}\ m_t + \frac{(\gamma-1)}{\gamma}\ \theta\ m_{t-1} + (1-\theta)p_{t+1}^e$$

(A-13b) $$p_{t+1}^e = \frac{\theta}{\gamma}\ m_{t+1}^e + \frac{(\gamma-1)}{\gamma}\theta\ m_t + (1-\theta)p_{t+2}^e$$

(A-13b) gives the value of m^e_{t+1} that is consistent with p^e_{t+2}, the independent variable.

(A-14) $$\frac{\theta}{\gamma} m^e_{t+1} = p^e_{t+1} - (\frac{\gamma-1}{\gamma}) \theta m_t - (1-\theta) p^e_{t+2}$$

Since

(A-15) $$f_t = \frac{\theta}{\gamma} m^e_{t+1} + \frac{(\gamma-1)}{\gamma} \theta m_t + (1-\theta) p^e_{t+2} - p^{*e}_{t+1}$$

(A-16) $$f_t = p^e_{t+1} - p^{*e}_{t+1}$$

Expected money supplies and the effects of lags in cash balance adjustments are subsumed in p^e_{t+1}.