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VECTOR AUTOREGRESSION ANALYSIS OF EXCHANGE RATE MOVEMENT

By

Rajiv Mallick
Basudeb Biswas
Vector Autoregression Analysis of Exchange Rate Movement

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&

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8:15-10:00 a.m., Exchange Rate I
I Introduction

Since 1973 when major nations adopted the floating exchange rate system there have been greater fluctuations in the exchange rate. Figures 1 and 2 show that both the real and the nominal exchange rates have moved together and both have fluctuated considerably in the post Bretton Woods era. The major reason for the greater volatility of the exchange rate is the move towards flexible exchange rates in the world economy. This volatility is regarded as a disequilibrium phenomenon. By disequilibrium it is meant that the exchange rate deviates in the short run from the long run equilibrium level. This deviation is regarded as a case of misalignment, and produces excess social welfare cost. The policy implication is that the government should intervene in the foreign exchange market to manage the floating rate. Left to market forces the exchange rate is determined by the demand and supply of foreign exchange. The demand for foreign currency stems from two sources, the desire to buy foreign goods and the desire to buy securities denominated in foreign currency. The supply of foreign currency comes from the foreigners' desire to buy securities denominated in domestic currency. Demand for goods and services remain stable in the short run since forces affecting the goods market change slowly. The highly volatile movements of the exchange rate can be attributed to changes in the assets markets. In this paper we analyze the determinants of the dollar-deutsche mark exchange rate within the framework of assets markets.

This paper is organized as follows. Section II briefly discusses the Dornbusch model (1976) and identifies the key variables determining the exchange rate. These macrovariables
Figures 1 & 2
are the dollar-deutsche mark exchange rate, the real money supply, and the real output. The forward exchange rate is another macrovariable which is used as a proxy for the expected change in the exchange rate. A vector autoregression model is used to find the interrelationships among these variables. Section III gives an outline of an econometric model showing the relationship among the exchange rate, the real money supply, the real income, and the forward rate. Empirical results are presented in section IV, and section V gives the concluding remarks.

II The Dornbusch Model

The building blocks of the Dornbusch model are (i) interest parity condition, (ii) perfect capital mobility, (iii) the expectation about change in the exchange rate, (iv) a money-market equilibrium condition, and (v) a price-level adjustment equation.

*Expected return on Deutsche Mark deposits*

The expected return on deutsche mark (DM) deposits measured in the US dollar is approximately equal to the German interest rate and the expected rate of depreciation of the dollar against the DM. Let \( R_{DM} \) denote the interest rate on DM deposits, \( E_{S/DM} \) denote the spot exchange rate i.e., the price of DM in terms of dollars and \( E_{S/DM}^e \) the expected $/DM exchange rate. Thus the expected return on DM deposits is

\[ R_{DM} + \frac{(E_{S/DM}^e - E_{S/DM})}{E_{S/DM}} \]  

(1)

The above expression measures the expected rate of return on a DM deposit in terms of the
DM interest rate and the expected rate of dollar depreciation against the DM. Under the assumption that the interest parity condition always holds, a forward exchange rate equals the expected exchange rate. The expected rate of return of a DM deposit measured in the US dollar should be compared with the US interest rate. This comparison is mathematically expressed as the following:

\[ R_s - [R_{DM} + (E_s^{e/DM} - E_s/DM)/E_s/DM] \] (2)

When the expression in (2) is positive, dollar deposits are preferred to DM deposits, and vice-versa. The foreign exchange market attains equilibrium when the domestic interest is equal to the expected dollar return on deposits denominated in DM. This condition is called the interest parity condition. The equilibrium condition is written as:

\[ R_s = R_{DM} + (E_s^{e/DM} - E_s/DM)/E_s/DM \] (3)

At equilibrium, deposit holders remain indifferent at the margin to holding deposits in different currencies. Therefore it can be said that the interest parity condition is a function of the US interest rate, the DM interest rate, and the forward exchange rate. When the interest parity condition holds, the foreign exchange market is in equilibrium. Figure 3 shows the equilibrium exchange rate at which \( R_s = R_{DM} + (E_s^{e/DM} - E_s/DM)/E_s/DM \).

If it is expected that the exchange rate is going to increase, the schedule showing the return on DM deposits measured in the US dollar shifts to the right for the given US interest rate, and the current spot rate increases. Figure 3 shows the comparative static result of a change in expectation of the current exchange rate. Since we take the forward exchange rate as a proxy for the expected change in the exchange rate we can postulate that an increase in the forward rate will raise the exchange rate. This hypothesis is tested.
Figure 3

Exchange Rate
($/DM)

Return on Dollar deposits

Return on DM deposits measured in the US dollar

Rate of Return (in: Dollar)
Interest Rate

Although the interest rate is determined in the money market, the exchange rate movements can be attributed to changes in the domestic and foreign interest rates. Given that the supply of money is exogenous, the interest rate is determined when the money market is in equilibrium. An increase in the money supply will lower the interest rate. A lower interest rate in the home country results in the net outflow of capital and the domestic currency will depreciate. Similarly an increase in the money supply in the foreign country will result in a lower foreign interest rate. There will be a net inflow of foreign capital and the exchange rate decreases. It is assumed that under the interest parity condition there is no excess demand for foreign currencies. This analysis indicates that the exchange rate and the real domestic money supply are positively related. As the real money supply increases the interest rate declines, which results in a depreciation of the domestic currency, and an increase in the exchange rate.

Interaction of Real Money Supply and Real GNP, and Price Level

Money market equilibrium is attained when the money supply equals the aggregate money demand. Thus the money supply and the money demand determine the interest rate, given that the output and the price level remain constant in the short run. An increase in the money supply will result in lower interest rate, in the short run, because of sluggish response of prices to changes in other economic variables. Similarly a higher money
demand will raise the interest rate, and domestic currency would appreciate. We now trace
the consequence of changes in the price-level on the interest rate, and the exchange rate.
Assuming that the price level and the output remain fixed in the short run, the money
market equilibrium is expressed as:

\[ \frac{M^S}{P} = L(R,Y) \quad (4) \]

where \( \frac{M^S}{P} \) is the real money supply, \( R \) is the interest rate, and \( Y \) is the output. In the
short run as the prices of goods and services do not react to increase in the money supply,
the interest rate declines more than the long-run level. This decline in the interest rate
leads changes in the expected exchange rate causing "overshooting" of the exchange rate in
the short run (Dornbusch, 1976). As prices start to respond to the increased money supply,
the real money supply is reduced and the interest rate as well as the exchange rate reach
the long-run equilibrium. Thus an increase in the price level results in a higher interest
rate. An increase in the interest rate is followed by a decrease in the exchange rate.

The analysis can be extended to determine the effect of a change in the domestic real
GNP on the exchange rate. An increase in the real GNP will increase the aggregate money
demand, and the interest rate will increase. When the interest rate increases, the exchange
rate decreases, i.e, pay less in domestic currency per unit of foreign currency. Thus an
increase in real domestic income has a negative effect on the exchange rate.

III Econometric Model
Econometric Modelling of the relationship among the exchange rate, the real money supply, the real output, and the forward rate

In this section we briefly explain the model and the methodology used in this paper. The model is based on the interest parity theory. The previous section explains how the real money supplies, and real incomes of countries, and the forward exchange rate explain the long run behavior of the $/DM exchange rate. Using the US-Germany quarterly data for the period 1960 to 1991, we empirically examine whether there is any long-run economic relationship among these variables. This is done by testing for cointegration among these variables.

Before testing for cointegration we need to test for stationarity and determine the order of integration of the time series. To test for stationarity (unit root) the Augmented Dickey-Fuller (ADF) tests were conducted on the time series. The following regression is performed to determine whether the time series is stationary or not (Dickey and Fuller 1979).

\[
(Y_t - Y_{t-1}) = \alpha + \beta_1 Y_{t-1} + \beta_2 (Y_{t-1} - Y_{t-2}) + \beta_3 (Y_{t-3} - Y_{t-2}) + \beta_4 (Y_{t-4} - Y_{t-3}) + \beta_5 t + \epsilon_t
\]  

In case of unit root $\beta_1$ will not be significantly different from zero and we accept the null hypothesis that the time series is not stationary. The next step would be to determine the order of integration. To determine the order of integration the stationarity of $Y_{t-1} - Y_{t-2}$ is checked. If it is found to be stationary, the conclusion is made that $Y_t$ is integrated of order...
Johansen's maximum likelihood model is used to test for cointegration (Dickey, Jansen, Thornton, 1991). This method is preferred to the other methods of testing cointegration because it uses the maximum likelihood estimation procedure which does not require a priori, the variable to be treated as the dependent one in estimating the cointegrating vector.

Johansen's method has two test statistics for the number of cointegrating vectors. These are the trace statistic and maximum eigenvalue statistic. The null hypothesis for the trace test is that the number of cointegrating vectors is less than or equal to \( r \), where \( r \) is 0, 1, 2, 3, 4, 5 or 6. In the maximum eigenvalue test the null hypothesis of \( r=0, r\leq 1, r\leq 2, r\leq 3, \) and \( r\leq 5 \) is tested against the alternative hypothesis of \( r= 1, 2, 3, 4, 5 \) or 6 (Dickey, Jansen and Thornton 1991). Johansen's maximum likelihood test for cointegration determines whether the lagged values of changes in a system of variables help explain the changes in the dependent variable.

The presence of cointegrating vector indicates a long run relationship among the variables. Error correction terms can be computed once the presence of the cointegrating vectors is established. In presence of cointegrating vector an error correction term will be included in the vector autoregression (VAR) model. The VAR is set up to explain the short run dynamics of the system.

### IV Data and Empirical Results

For this paper data on the US $/DM exchange rate, the forward exchange rate, the real
money supply and the real income for Germany and the US were obtained from various issues of International Financial Statistics of the International Monetary Fund. The forward exchange rate is taken as a proxy for the expected exchange rate \((E_{S/DM})\) in equation (1). The data sets were initially tested for stationarity (or unit root). The ADF tests were performed on all time series. The null hypothesis is that the time series has unit root. A higher absolute value of the Dickey-Fuller t-statistic compare to that of the MacKinnon values at 5% level of significance leads to rejection of the null hypothesis, i.e., data set is stationary. Table 1 presents the results of Augmented Dickey-Fuller Test for the time series in levels and their first difference.

Table 1

<table>
<thead>
<tr>
<th>Variables</th>
<th>D-F(^1)</th>
<th>D-F(^\Delta)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exchange Rate</td>
<td>-2.126</td>
<td>-5.233*</td>
</tr>
<tr>
<td>Forward Rate</td>
<td>-1.813</td>
<td>-5.964*</td>
</tr>
<tr>
<td>Real US GNP</td>
<td>-3.041</td>
<td>-5.593*</td>
</tr>
<tr>
<td>Real German GNP</td>
<td>-1.409</td>
<td>-9.529*</td>
</tr>
<tr>
<td>Real German Money</td>
<td>0.022</td>
<td>-11.005*</td>
</tr>
<tr>
<td>Real US Money</td>
<td>-1.549</td>
<td>-12.007*</td>
</tr>
</tbody>
</table>

\(^1\) Dickey-Fuller t-statistics
MacKinnon Critical Values (5%) = -3.446
* Statistically significant at the 5 percent level of significance.

Table 1 shows the results of the ADF test for unit root for all variables. A higher absolute
value of MacKinnon critical value than the absolute value of the Dickey-Fuller t-statistics at the 5% level of significance would reject the null hypothesis of nonstationarity and accept the alternative hypothesis that the time series is stationary. Table 1 indicates that all the variables are nonstationary at their levels and are integrated of order one.

Exchange Rate and Forward Rate

We find that both the exchange rate and the forward exchange rate are integrated of order one. Our theoretical analysis suggests that an increase in the forward rate will cause an increase in the spot rate. We run a regression of the exchange rate on the forward rate. The variables are used in their first differences.

\[ \Delta E_t = \beta_1 + \beta_2 \Delta F_t + \beta_3 \Delta F_{t-1} + \nu_t \]  

(6)

where \( \Delta E_t \) is the first difference of the exchange rate, \( \Delta F_t \) is the first difference of the forward rate, and \( \Delta F_{t-1} \) is the lagged values of the first difference of the forward rate.

Results of this regression is reported in table 2.

Table 2

<table>
<thead>
<tr>
<th>Dependent Variable is ( \Delta E_t )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable</td>
</tr>
<tr>
<td>C</td>
</tr>
<tr>
<td>( \Delta F_t )</td>
</tr>
<tr>
<td>( \Delta F_{t-1} )</td>
</tr>
</tbody>
</table>

R² = 0.82, F-stat = 273.37

* Significant at 5%
Results indicate that there is a positive association between the forward rate and the exchange rate. This result is also verified using the cointegration test.

\textit{Test for Cointegration}

It was determined that the exchange rate, the forward exchange rate, the real money supply of the US and Germany, the real income of the US and Germany are integrated of order one. To determine a long run relationship among them, we do the Johansen Maximum Likelihood test for cointegration. The results of the test are presented in table 3.

\textbf{Table 3}

\begin{center}
\begin{tabular}{l l l}
\hline
Null & Alternative & Statistic \\
\hline
\(r=0\) & \(r=1\) & 90.4113* \\
\(r\leq1\) & \(r=2\) & 60.7465* \\
\(r\leq2\) & \(r=3\) & 17.1410 \\
\(r\leq3\) & \(r=4\) & 7.9272 \\
\(r\leq4\) & \(r=5\) & 4.8655 \\
\(r\leq5\) & \(r=6\) & 3.6238 \\
\hline
\end{tabular}
\end{center}

* Statistically significant at the 5 percent level of significance.

According to the above results there are two cointegrating vectors.
Table 4

Johansen Maximum Likelihood Method Cointegration LR Test
Based on Trace of the Stochastic Matrix

<table>
<thead>
<tr>
<th>Null</th>
<th>Alternative</th>
<th>Statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>( r = 0 )</td>
<td>( r \geq 1 )</td>
<td>184.7155*</td>
</tr>
<tr>
<td>( r \leq 1 )</td>
<td>( r \geq 2 )</td>
<td>94.3042*</td>
</tr>
<tr>
<td>( r \leq 2 )</td>
<td>( r \geq 3 )</td>
<td>33.5576</td>
</tr>
<tr>
<td>( r \leq 3 )</td>
<td>( r \geq 4 )</td>
<td>16.4166</td>
</tr>
<tr>
<td>( r \leq 4 )</td>
<td>( r \geq 5 )</td>
<td>8.4894</td>
</tr>
<tr>
<td>( r \leq 5 )</td>
<td>( r \geq 6 )</td>
<td>3.6238</td>
</tr>
</tbody>
</table>

* Statistically significant at the 5 percent level of significance.

According to the above results there are two cointegrating vectors. The cointegrating vectors are reported in Table 6 with the normalized values in brackets. Table 5 tabulates the ADF test results of the residuals of the cointegrating vectors.

Table 5

Augmented Dickey-Fuller Tests for Unit Root for the residuals of Johansen Maximum Likelihood Method with four lags

<table>
<thead>
<tr>
<th>Residual</th>
<th>Statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>RES1</td>
<td>-4.6256*</td>
</tr>
<tr>
<td>RES2</td>
<td>-3.1431</td>
</tr>
</tbody>
</table>

MacKinnon Critical Values (5%) = -3.4478

* Statistically significant at the 5 percent level of significance.
Table 6

Estimated Cointegrated Vectors in Johansen Estimation. Normalized values are in brackets. Maximum lag in VAR = 4, chosen r = 2

<table>
<thead>
<tr>
<th></th>
<th>Vector 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>24.7916 (1.0000)</td>
</tr>
<tr>
<td>RUSMS</td>
<td>-0.04071 (0.0016)</td>
</tr>
<tr>
<td>RGMS</td>
<td>-0.00371 (0.1459E-3)</td>
</tr>
<tr>
<td>RGGNP</td>
<td>-0.01457 (0.5876E-3)</td>
</tr>
<tr>
<td>RUSGNP</td>
<td>0.01632 (-0.6584E-3)</td>
</tr>
<tr>
<td>F</td>
<td>-25.1279 (1.0136)</td>
</tr>
</tbody>
</table>

Note: E, RUSMS, RGMS, RGGNP, RUSGNP, and F denote the nominal exchange rate, the real US money supply, the real German money supply, the real German GNP, the real US GNP and the forward exchange rate respectively.

Augmented Dickey Fuller test on the residuals indicate that there is only one cointegrating vector with stationary residuals. Therefore it is concluded that there is one cointegrating vector. That is, there exists a long run relationship among real money supplies and real incomes of the US and Germany, the exchange rate and the forward rate. A test for cointegration is a pretest to avoid "spurious regression". All variables are assumed to be jointly endogenous. The elements in the cointegration vector should not be interpreted in the same manner as the structural coefficients of an equation in the system of simultaneous equations. However, the signs of coefficients of the exchange rate and the forward rate are consistent with the hypothesized direction. The short run dynamics of the model can be explained using a vector error correction model.

*Vector Error Correction Model*

In our investigation, we find that there is one cointegrating vector with stationary residuals.
This result indicates that one linear combination of the variables exists which can explain the long run relationship among them. According to the Granger representation theorem, the presence of a cointegrating vector can be helpful in explaining the short-run dynamics. To explain the short run dynamics the vector error correction model (VECM) is developed.

The VECM is a system of equations in which endogenous variables are a linear function of its past values, past values of other endogenous variables in the system, exogenous variables whose lagged values are considered as endogenous variables, and constant terms and the error correction term. This model is used to analyze the dynamic effects of random disturbances. The following series of regressions are performed and the results are analyzed.

\[
\Delta E_t = c_1 + \rho_1 \Delta E_{t-1} + \text{lagged}(\Delta E_t, \Delta F_t, \Delta RGPNP_t, \Delta RUSGNP_t, \Delta RGMS_t, \Delta RUSMS_t) + \epsilon_1t
\]  
(7)

\[
\Delta F_t = c_2 + \rho_2 \Delta F_{t-1} + \text{lagged}(\Delta E_t, \Delta F_t, \Delta RGPNP_t, \Delta RUSGNP_t, \Delta RGMS_t, \Delta RUSMS_t) + \epsilon_2t
\]  
(8)

\[
\Delta RGPNP_t = c_3 + \rho_3 \Delta F_{t-1} + \text{lagged}(\Delta E_t, \Delta F_t, \Delta RGPNP_t, \Delta RUSGNP_t, \Delta RGMS_t, \Delta RUSMS_t) + \epsilon_3t
\]  
(9)
\[ \Delta \text{RUSGNP}_t = c_4 + \rho_4 z_{t-1} + \text{lagged}(\Delta E, \Delta F, \Delta \text{RGGNP}) + \Delta \text{RUSGNP}_t \Delta \text{RGMS}_t \Delta \text{RUSMS}_t + \epsilon_{4t} \] (10)

\[ \Delta \text{RGMS}_t = c_5 + \rho_5 z_{t-1} + \text{lagged}(\Delta E, \Delta F, \Delta \text{RGGNP}) + \Delta \text{RUSGNP}_t \Delta \text{RGMS}_t \Delta \text{RUSMS}_t + \epsilon_{5t} \] (11)

\[ \Delta \text{RUSMS}_t = c_6 + \rho_6 z_{t-1} + \text{lagged}(\Delta E, \Delta F, \Delta \text{RGGNP}) + \Delta \text{RUSGNP}_t \Delta \text{RGMS}_t \Delta \text{RUSMS}_t + \epsilon_{6t} \] (12)

where \( z_{t-1} \) is the error correction term obtained from the cointegration test, \( \rho_1, \rho_2, \rho_3, \rho_4, \rho_5 \) and \( \rho_6 \) are the coefficients of the error correction term, and at least one of them should be nonzero, \( \epsilon_{1t}, \epsilon_{2t}, \epsilon_{3t}, \epsilon_{4t}, \epsilon_{5t} \) and \( \epsilon_{6t} \) are white noise, and \( \Delta E, \Delta F, \Delta \text{RGGNP}, \Delta \text{RUSGNP}, \Delta \text{RGMS}, \) and \( \Delta \text{RUSMS} \) are the first differences of the exchange rate, the forward rate, the real income of Germany, the real income of the US, the real money supply of Germany, and the real money supply of the US respectively. The regression results are reported in appendix 1.

In two of the VECM regressions (equations 7 and 12) the coefficients of the error correction terms are significant. The lagged values of the first difference of the exchange
rate, the forward exchange rate, the real money supply of Germany, and the real money supply of the US are found significant in some of the VECM regression.

Though VECM has been used very often with a system of equations for forecasting purposes, its use as a forecasting tool for economic variables is controversial. The empirical results obtained from VECMs are not stable or robust. This indicates that VECM statistics may be sensitive to modifications to VECM's random and non-random parts (Todd, 1990). It would be desirable to check for stability, though it is not easy to do so using current techniques.

To interpret the coefficients of the VECM model, a common practice is to analyze impulse response functions and variance decompositions of the system. The impulse response function measures the response of shocks on endogenous variable over time in itself or in another variable, and how they filter through the model to affect other variables. In interpreting the impulse response function the common practice is to attribute all the effects of such common components of shocks to the dependent variable of the first equation in the model.

The results of impulse response function indicate that there is insignificant effect of one standard deviation in the first differences of each variables on the VECM. These results indicate that there should be less volatility in the exchange rate, which is contrary to what is generally observed. The impulse response function also indicates that the growth in the exchange rate is positive initially and becomes negative in the fourth quarter in response to a one standard deviation positive shock in the growth in the real money supply of the US (see table 7, figure 4). The negative effect persists for over a long period of time.
Table 7

Response to one Standard Deviation Shock of $\Delta RUSMS$

<table>
<thead>
<tr>
<th>Period</th>
<th>$\Delta E$</th>
<th>$\Delta F$</th>
<th>$\Delta RGMS$</th>
<th>$\Delta RUSMS$</th>
<th>$\Delta RGGNP$</th>
<th>$\Delta RUSGNP$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.000000</td>
<td>0.000000</td>
<td>0.000000</td>
<td>0.099447</td>
<td>0.045293</td>
<td>0.020883</td>
</tr>
<tr>
<td>2</td>
<td>0.001013</td>
<td>0.002153</td>
<td>-0.010753</td>
<td>-0.016729</td>
<td>-0.009680</td>
<td>0.217511</td>
</tr>
<tr>
<td>3</td>
<td>0.001025</td>
<td>0.003612</td>
<td>0.003476</td>
<td>0.012859</td>
<td>-0.008457</td>
<td>-0.088643</td>
</tr>
<tr>
<td>4</td>
<td>-0.000117</td>
<td>0.002362</td>
<td>0.019337</td>
<td>0.043101</td>
<td>-0.012048</td>
<td>-0.154922</td>
</tr>
<tr>
<td>5</td>
<td>-0.001206</td>
<td>0.001141</td>
<td>0.020653</td>
<td>0.145361</td>
<td>0.013348</td>
<td>0.043659</td>
</tr>
<tr>
<td>6</td>
<td>-0.002037</td>
<td>0.001794</td>
<td>-0.002772</td>
<td>0.052383</td>
<td>-0.017856</td>
<td>0.205962</td>
</tr>
<tr>
<td>7</td>
<td>-0.001698</td>
<td>0.002753</td>
<td>0.014188</td>
<td>0.091862</td>
<td>-0.001303</td>
<td>0.115830</td>
</tr>
<tr>
<td>8</td>
<td>-0.001164</td>
<td>0.004315</td>
<td>0.029420</td>
<td>0.120889</td>
<td>0.017306</td>
<td>0.125579</td>
</tr>
<tr>
<td>9</td>
<td>-0.000777</td>
<td>0.005980</td>
<td>0.041039</td>
<td>0.231234</td>
<td>0.029530</td>
<td>0.199715</td>
</tr>
<tr>
<td>10</td>
<td>-0.001667</td>
<td>0.006692</td>
<td>0.017779</td>
<td>0.179455</td>
<td>-0.004449</td>
<td>0.254856</td>
</tr>
<tr>
<td>11</td>
<td>-0.002166</td>
<td>0.007956</td>
<td>0.037875</td>
<td>0.250012</td>
<td>0.014171</td>
<td>0.224633</td>
</tr>
<tr>
<td>12</td>
<td>-0.002315</td>
<td>0.011149</td>
<td>0.057237</td>
<td>0.307829</td>
<td>0.034836</td>
<td>0.326869</td>
</tr>
</tbody>
</table>

where $E$ is the exchange rate, $F$ is the forward rate, $RGGNP$ is the real income of Germany, $RUSGNP$ is the real income of the US, $RGMS$ is the real money supply of Germany, and $RUSMS$ is the real money supply of the US.

**Figure 4**  Response to one SD shock in $RUSMS$

![Graph showing the response to one SD shock in RUSMS over different periods](image-url)
This finding can be interpreted as the short run "overshooting" phenomenon of the exchange rate (Dornbusch, 1976).

The variance decomposition results should be interpreted with some caution. The results may vary with changes in the order of the time series. Most of the variables except the forward exchange rate explain most of their own variances. In most of the cases the innovation is captured by the exchange rate and the forward rate in a span of two to four quarters. Other variables have limited role in explaining innovations.

V Conclusion

This paper examines the relationship among the exchange rate, the forward rate, the real incomes and the real money supplies of Germany and the US. The forward exchange rate is used as a proxy for the expected exchange rate. Johansen's maximum likelihood method is used to estimate the cointegrating vector, and explain the long run relation among these variables. We find that the exchange rate and the forward rate move very closely. The forward rate is found to be a good indicator of the expected exchange rate. Empirical results of the analysis indicate that the forward rate explains significantly the movements in the exchange rate. The cointegration test indicates that there exists a long run relationship among the variables. The cointegration test also indicates that there is an inverse relation between the exchange rate and the domestic real income. Results of the vector error correction model show that the shocks in the real US money supply have an "overshooting" effect on the exchange rate. Variance decomposition analysis of the model indicates that
most of the innovation is captured by the exchange rate and the forward rate.

The findings of the analysis are that the changes in the expectation regarding the exchange rate is well captured by the forward rate. The exchange rate and the forward rate move very closely. The notion of exchange rate "overshooting" is also found to be relevant in this case. In foreign exchange markets innovations are well captured by changes in the exchange rate and the forward rate.
References


### Appendix 1

#### Vector Error Correction Model - Parameters Estimates

<table>
<thead>
<tr>
<th>Explanatory variable</th>
<th>Dependent variable ΔE</th>
<th>Dependent variable ΔF</th>
<th>Dependent variable ΔRGMS</th>
<th>Dependent variable ΔRUSMS</th>
<th>Dependent variable ΔRGGNP</th>
<th>Dependent variable ΔRUSGNP</th>
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</thead>
<tbody>
<tr>
<td>ΔE₁</td>
<td>0.3412</td>
<td>-0.142</td>
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<td>ΔRGMS₂</td>
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<td>-0.051</td>
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<td>ΔRGMS₃</td>
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<td>0.0049</td>
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<tr>
<td>ΔRUSGNP₂</td>
<td>-0.0004</td>
<td>-0.001</td>
<td>0.0077</td>
<td>-0.008</td>
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<td>-0.405*</td>
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<tr>
<td>ΔRUSGNP₃</td>
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<td>0.0011</td>
<td>-0.011</td>
<td>-0.009</td>
<td>0.0059</td>
<td>-0.252*</td>
</tr>
<tr>
<td>ΔRUSGNP₄</td>
<td>0.0003</td>
<td>0.0021</td>
<td>0.0017</td>
<td>-0.004</td>
<td>0.0013</td>
<td>-0.081</td>
</tr>
<tr>
<td>C</td>
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<tr>
<td>Z₁</td>
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<td>-9.56</td>
<td>-54.83</td>
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<td>R²</td>
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<td>0.74</td>
<td>0.87</td>
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<td>F-stat</td>
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<td>10.49</td>
<td>25.15</td>
<td>1.489</td>
<td>3.054</td>
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</tbody>
</table>

* Statistically significant at 5%

where E is the exchange rate, F is the forward rate, RGGNP is the real income of Germany, RUSGNP is the real income of the US, RGMS is the real money supply of Germany, and RUSMS is the real money supply of the US.