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**Some Evidence on Exchange Rate Determination in Major Industrial Countries**

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**Abstract**

This paper examines the role of long-run monetary and cyclical factors in determining exchange rate movements. Results of empirical study using a data set that includes Canada, Germany, Japan, the United Kingdom, and the United States support the view that exchange rate movements can be explained by the efficient or rational adjustment of foreign exchange markets to economic fundamentals. In the long run, the exchange rate is determined consistent with a monetary approach to exchange rates, while cyclical factors have an impact on short-run exchange rate dynamics. Estimated equations outperform random walk models of exchange rates.

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## SUMMARY

This paper examines the role of long-run monetary and cyclical factors in determining exchange rate movements. A conventional macroeconomic model with rational expectations is first presented that illustrates key aspects of exchange rate determination in a world of high capital mobility and low sovereign risks. The paper shows that, under a deterministic monetary rule, bilateral exchange rates reflect long-run monetary and cyclical factors.

Empirical analysis is applied to a data set that includes Canada, Germany, Japan, the United Kingdom, and the United States. This analysis first confirms that bilateral exchange rates are cointegrated with bilateral economic fundamentals. Next, single-equation estimates of the U.S. dollar-deutsche mark and U.S. dollar-Japanese yen exchange rates are presented. The estimated equations exhibit stable in- and out-of-sample parameter estimates. The single-equation estimates are shown to outperform, and to encompass, random walk models of the exchange rate. These findings are consistent with a view that exchange markets behave rationally and reflect economic fundamentals.

The empirical results show that in the long run, the exchange rate is explained by the variables predicted by the monetary model. Current account balances have an impact on the short-run dynamics of exchange rate movement in some cases, but do not affect the long-run level of the exchange rate. This evidence is consistent with the view that, in a world of high capital mobility, exchange rates are more a monetary phenomenon in the long run.

## I. INTRODUCTION

The concept of exchange rate misalignment is a somewhat problematic one reflecting our imperfect knowledge of exchange market behavior. Although there have been some episodes when foreign exchange markets have exhibited trends that are widely seen as incompatible with economic fundamentals, nevertheless, at any point in time, it is difficult to know what explains exchange rate movements and whether a perceived “misalignment” is the result of a “market failure”, or a “model failure”, or a “policy failure.” This is essentially the dilemma facing the policymaker in deciding what, if any, action to take in response to exchange rate movements. It is imperative, therefore, that a satisfactory approach to modeling exchange rate movements which can be supported by empirical evidence be developed to aid our understanding of exchange rate movements, and the formulation of suitable policy responses.

One approach to modeling exchange rate movements and inferring exchange rate misalignments focuses on some notion of a fundamental real equilibrium exchange rate (REER). This is a central concept in the work which has focused on the relationship between savings-investment balances and sustainable current account positions (see Masson, Isard, and Faruquee (1996)). This approach is, however, subject to certain shortcomings and qualifications. First, the emphasis on the REER does not give adequate attention to the monetary and asset price aspects of exchange rate, properties which have long been recognized (Hume, 1752). Second, the specific approach to modeling the relationship between the savings-investment balance and the current account has not, in most cases, taken into account the implications of high capital mobility for the sustainability of current account positions. Third, the nature of any policy action will depend on whether the market exchange rates reflect economic fundamentals and a view needs to be established on this matter in the first place.

This paper presents an alternative approach to analyzing exchange rates. First, a model based on a conventional description of goods and money markets illustrates the role of monetary and cyclical factors in exchange rate determination in a world of high capital mobility. Second, an empirical examination is made of the role of both real factors and monetary factors in the determination of exchange rate movements using a data set which includes five OECD countries: Canada, Germany, Japan, United Kingdom, and the United States.

The results throw light on the issues raised above. First, the results support the view that exchange rate movements can be explained by the efficient or rational adjustment of foreign exchange markets to economic fundamentals. Consequently, what is often perceived as an “exchange rate misalignment” may not, in fact, be the result of a market failure but rather the failure of policies to achieve the desired outcomes.

Second, the evidence is consistent with the view that exchange rates are, in the long run, determined consistent with an approach which attributes importance to monetary factors.

No empirical support is found for the current account balance affecting the long-run level of the exchange rate. However, the short-run dynamics of the exchange rate are strongly influenced by cyclical factors and there is some evidence that the current account balances can have an impact in this regard. Consequently, an approach which seeks to determine an "appropriate" exchange rate solely from an assessment of a country's current account balance, or the savings and investment balance, is rather limited and misplaced in its focus.

The paper is organized as follows: Section II presents a model which emphasizes monetary factors. Section III discusses the empirical analyses of bilateral exchange rates, explains in detail the data used in this paper, and performs cointegration analysis. In Section IV, single-equation estimation is carried out for the deutsche mark/U.S. dollar and the Japanese yen/U.S. dollar exchange rates, and the results are compared with the simple random walk model in terms of both forecast performance and explanatory power. Section V provides concluding remarks.

## II. AN ILLUSTRATIVE MODEL OF THE EXCHANGE RATE

It is a truism that the exchange rate is the price of monies. Therefore any attempt to understand exchange rate behavior cannot ignore the impact of monetary variables. Moreover, in countries with well developed financial markets and freedom of capital flows, the exchange rate can best be treated as an asset price determined in the money market.<sup>2</sup>

The following section sets out a simple model of exchange rate movements which serves to illustrate the channels through which inflation, interest rates, and excess demand conditions of different countries affect exchange rates through highly integrated international financial markets in a world of high capital mobility and low sovereign risks.

The economy consists of markets for goods, domestic money, and domestic and foreign bonds. We assume that people never hold foreign currency in a monetary form, and they hold only foreign bonds. Implicitly, we assume that there is a foreign exchange market, so there is no transaction need for foreign money, if the spot foreign exchange market can facilitate all current account transactions. In general equilibrium analysis, we can treat one market as a residual, and in the following model, the foreign bond market is not explicitly studied.

We make three operational assumptions which have important implications for the model.

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<sup>2</sup>This approach is consistent, and can be complemented, with an approach based on purchasing power parity which states that in the long run, the exchange rate reflects the relative price of goods across countries. See for example Brewer (1994), Frost and Rogoff (1995), and Rogoff (1996).

Assumption 1: Monetary policy is used to target the price level under a deterministic rule.

As pointed out in Sargent and Wallace (1975), under perfect foresight, when the loss function includes quadratic terms in the price level, the optimal monetary policy is one that equates the expected value of next period's price level to the target value. However, the model can be expanded to accommodate different specifications of monetary policy.

Assumption 2: Actual and potential output, current and future, are given exogenously.

This assumption is adopted to simplify the model, but it can also be regarded as the outcome of a well defined structural model under the monetary policy rule specified in assumption 1. For example, assume an aggregate supply schedule of the following form:

$$y_t = a_1 k_t + a_2 (p_t - E_{t-1} p_t) + \epsilon_t \quad (1)$$

where  $k_t$  is a measure of productive capacity, and changes in  $k_t$  are affected by real interest rates only. (Note this "natural rate hypothesis" assumes that only unexpected increases in prices raise aggregate supply.) Under a deterministic money supply rule, monetary policy will not affect output because it will not cause unanticipated changes in inflation (see Sargent and Wallace (1975)).

Assumption 3: Under conditions of high capital mobility, the covered interest rate parity condition governs the equilibrium in the domestic bond and foreign exchange market.

The covered interest parity condition can be written as  $\frac{e^f}{e} = \frac{1+i}{1+i^*}$  where  $i$  is the domestic interest rate,  $i^*$  is the foreign interest rate and  $e$  is the exchange rate—the price of foreign currency in domestic currency units, and  $e^f$  is the forward rate. Taking logs this can be approximated to  $\log \left( \frac{e^f}{e} \right) = i - i^*$ . Under rational expectations we can approximate  $e^f$  to  $e_{t+1}$ , the actual exchange rate in the next period. Hence, the covered interest parity condition can be expressed as:

$$i_t = i_t^* + \Delta e_t \quad (2)$$

where,  $\Delta e_t$  is the actual change in the exchange rate in logs.

### IS Schedule

Equilibrium in the goods market is characterized by a reduced form equation for the interest rate that is affected by expected inflation and excess demand in the economy:

$$i_t = E_t p_{t+1} - p_t + \alpha - \beta y_t + u_t \quad (3)$$

where  $\alpha$  and  $\beta$  are constants, and  $u_t$  is the disturbance to the IS schedule and is assumed to be white noise.

### LM Schedule

The conventional portfolio balance equation characterizes money market equilibrium:

$$m_t - p_t = ay_t - bi_t + v_p \quad (4)$$

where  $v_t$  is the disturbance to demand for real balances and is assumed to be white noise too.

### Prices and money supply

To target the price level, the monetary authority needs to follow a specific monetary rule. This rule can be derived as follows. From equations (3) and (4), we have

$$p_t = m_t + b\alpha + b(E_t p_{t+1} - p_t) - (a + b\beta)y_t + w_p \quad (5)$$

where  $w_t = bu_t - v_t$

Under the monetary policy rule which is assumed to be credible to market participants, and assuming perfect foresight, expected future price levels are equal to the target price levels (denoted by bars in the following) e.g.:

$$E_{t-1} p_{t+1} = \bar{p}_{t+1}, \quad E_{t-1} p_t = \bar{p}_t \quad (6)$$

Taking  $E_{t-1}$  of equation (5) and using the above for expected values, we have the deterministic rule for the money supply, given the targeted values for the price level:

$$\bar{p}_t = m_t + b\alpha + b(\bar{p}_{t+1} - \bar{p}_t) - (a + b\beta)E_{t-1} y_t \quad (7)$$

### Interest Rate and Exchange rate determination

Under the deterministic money supply rule which determines the expected future price level, the interest rate can be determined from equation (3). Similar results can be obtained for the foreign country. The exchange rate can be derived by rewriting equation (2) as follows:

$$\Delta e = i - i^* = (\pi - \pi^*) + (\alpha - \beta y) - (\alpha^* - \beta^* y^*) + (u - u^*) \quad (8)$$

where  $\pi$  denotes expected and targeted inflation, and foreign variables are denoted by asterisks.

Equation (8) shows that according to the covered interest parity condition, the change in the exchange rate reflects the difference in targeted inflation, the difference in excess demand and the demand shocks in the two countries. Where monetary policy is used to target the price level under a deterministic rule, the interest rate is determined solely from the IS schedule, and the monetary variable (M) does not enter the equation explicitly but is reflected in the targeted inflation. The change in the exchange rate will reflect long-term monetary factors—the difference in inflation rates, as well as cyclical, and shock factors.

For estimation purposes, we would expect a more complex relationship than equation (8). The expected future exchange rate may differ from the forward rate, resulting in a more complex lag structure and the inclusion of interest rates as separate explanatory variables. The existence of excess demand and demand shocks may also be reflected in a country's current account balances of payments. Covered interest rate parity conditions would also be affected by changes in country specific risk premium which might be sensitive to a country's current account position.

### III. EMPIRICAL ANALYSIS OF BILATERAL EXCHANGE RATES

Finding of a robust empirical relationship to explain exchange rate movements has eluded many researchers. Empirically, it has been widely accepted that theoretical models which claim that economic fundamentals have a strong impact on exchange rate neither explain nor forecast exchange rate movements more satisfactorily than a simple random walk model. (See for example, Meese and Rogoff (1983). See also MacDonald (1995) for a more recent survey.) Recently, some researchers have found more satisfactory evidence that exchange rates respond to economic fundamentals when using real or effective exchange rates. For example, Razzak (1996) modeled a trade-weighted U.S. dollar exchange rates with some success compared to the results of the random walk model, and confirmed that economic fundamentals do explain exchange rates in the long run, and that volatility of the exchange rate is caused by volatility of these fundamentals. MacDonald (1997) presented evidence of significant and sensible long-run relationship using data on real effective exchange rates of the U.S. dollar, deutsche mark, and Japanese yen.

In the following sections, we first use a data set which includes five industrial countries: Canada, Germany, Japan, United Kingdom, and the United States, to ascertain whether, as predicted by theory, there are long-run relationships between exchange rates and economic fundamentals such as output, interest rates, inflation, and current account balances. The result shows existence of long-run "cointegration" of the exchange rate with economic

variables. The second part of the work, presented in Section IV, examines single-equation estimates of bilateral nominal exchange rates using variables that would be implied by the monetary model. The tested down single-equations provide stable estimates which encompass random walk models of exchange rates.

### **A. Summary of Data**

The data set used in this study includes the following variables: three-month interest rate, inflation, real GDP, and current account balances for Canada, Germany, Japan, United Kingdom, and United States, and exchange rates of the deutsche mark, yen, the pound sterling, and Canadian dollar expressed in terms of U.S. dollar. The quarterly observations cover a time span from 1973Q3 to 1996Q4, a period of the floating exchange rate regime following the break down of the Bretton Woods system. Figures 1–6 present general pictures of the data, and Table 1 summary statistics of the data. The sources and contents of the data are explained in detail in the Appendix.

#### **Exchange rates**

There have been large movements in exchange rates during this sample period. The U.S. dollar has generally depreciated against the deutsche mark and yen, but appreciated against the pound sterling and Canadian dollar. However, the processes were far from smooth (see Figure 1). Shortly after the floating of exchange rate, the U.S. dollar depreciated against the deutsche mark in 1975–80, and then appreciated sharply against it during the next five years. However, from 1985–88, the U.S. dollar depreciated against the deutsche mark even more sharply ending at an overall depreciated level by 1988. With respect to the pound sterling, the U.S. dollar first appreciated and then depreciated to the previous level in 1973–80. From late 1980 on, it appreciated again, but more persistently until 1985, and saw only partial depreciation afterwards ending at a generally appreciated level at the end of the period. The U.S. dollar's appreciation against Canadian dollar was fairly persistent in 1977–87. It depreciated partially in 1987–92, and was on an appreciating path since 1992. The Japanese yen's appreciation against the U.S. dollar is by far the most persistent with only brief periods of small depreciation. However, since late 1995, the dollar has been on an appreciating path against yen.

#### **Interest rates**

In the period studied, there were also large movements in interest rates, but the pattern is a little more synchronized than for exchange rate movements. An exception is that Japan's interest rates were generally lower and relatively more stable than those of others (see Figure 2). Among the five countries, the United Kingdom has on average the highest interest rates, followed by Canada, the United States, Germany, and Japan (see Table 1).

Table 1. Summary Statistics

| Series | Obs | Mean   | Std Error | Minimum | Maximum |
|--------|-----|--------|-----------|---------|---------|
| UKER   | 94  | -0.56  | 0.17      | -0.88   | -0.15   |
| GEER   | 94  | 0.70   | 0.22      | 0.32    | 1.15    |
| CAER   | 94  | 0.19   | 0.11      | -0.03   | 0.34    |
| JAER   | 94  | 5.19   | 0.37      | 4.44    | 5.72    |
| USI    | 94  | 7.15   | 2.76      | 2.98    | 15.09   |
| UKI    | 93  | 10.10  | 2.88      | 4.82    | 16.04   |
| GEI    | 93  | 6.70   | 2.69      | 3.26    | 14.37   |
| CAI    | 94  | 9.24   | 3.22      | 2.89    | 20.15   |
| JAI    | 92  | 3.27   | 1.36      | 0.30    | 6.00    |
| USPI   | 93  | 0.01   | 0.01      | 0.00    | 0.04    |
| UKPI   | 93  | 0.02   | 0.02      | -0.01   | 0.09    |
| GEPI   | 93  | 0.01   | 0.01      | -0.01   | 0.03    |
| CAPI   | 92  | 0.01   | 0.01      | -0.01   | 0.03    |
| JAPI   | 92  | 0.01   | 0.01      | -0.01   | 0.09    |
| USGDP  | 93  | 8.47   | 0.16      | 8.18    | 8.74    |
| UKGDP  | 93  | 6.16   | 0.14      | 5.95    | 6.39    |
| GEGDP  | 94  | 2.75   | 0.08      | 2.63    | 2.89    |
| CAGDP  | 93  | 6.33   | 0.19      | 5.96    | 6.60    |
| JAGDP  | 93  | 12.71  | 0.25      | 12.29   | 13.06   |
| USCA   | 92  | -15.77 | 16.51     | -46.08  | 15.06   |
| UKCA   | 92  | -1.54  | 3.64      | -11.60  | 6.14    |
| GECA   | 92  | 2.06   | 6.48      | -11.97  | 18.88   |
| CACA   | 92  | -2.45  | 2.40      | -9.25   | 1.36    |
| JACA   | 92  | 6.26   | 5.74      | -4.08   | 16.23   |
| UKID   | 93  | 1.01   | 0.01      | 0.99    | 1.02    |
| GEID   | 93  | 1.00   | 0.01      | 0.99    | 1.02    |
| CAID   | 94  | 1.01   | 0.00      | 0.99    | 1.01    |
| JAID   | 92  | 0.99   | 0.01      | 0.97    | 1.00    |
| DUKER  | 93  | 0.00   | 0.06      | -0.14   | 0.16    |
| DGEER  | 93  | 0.00   | 0.06      | -0.15   | 0.14    |
| DCAER  | 93  | 0.00   | 0.02      | -0.06   | 0.05    |
| DJAER  | 93  | -0.01  | 0.06      | -0.17   | 0.15    |

Figure 1. Exchange Rates Against the U.S. Dollar (in logs)

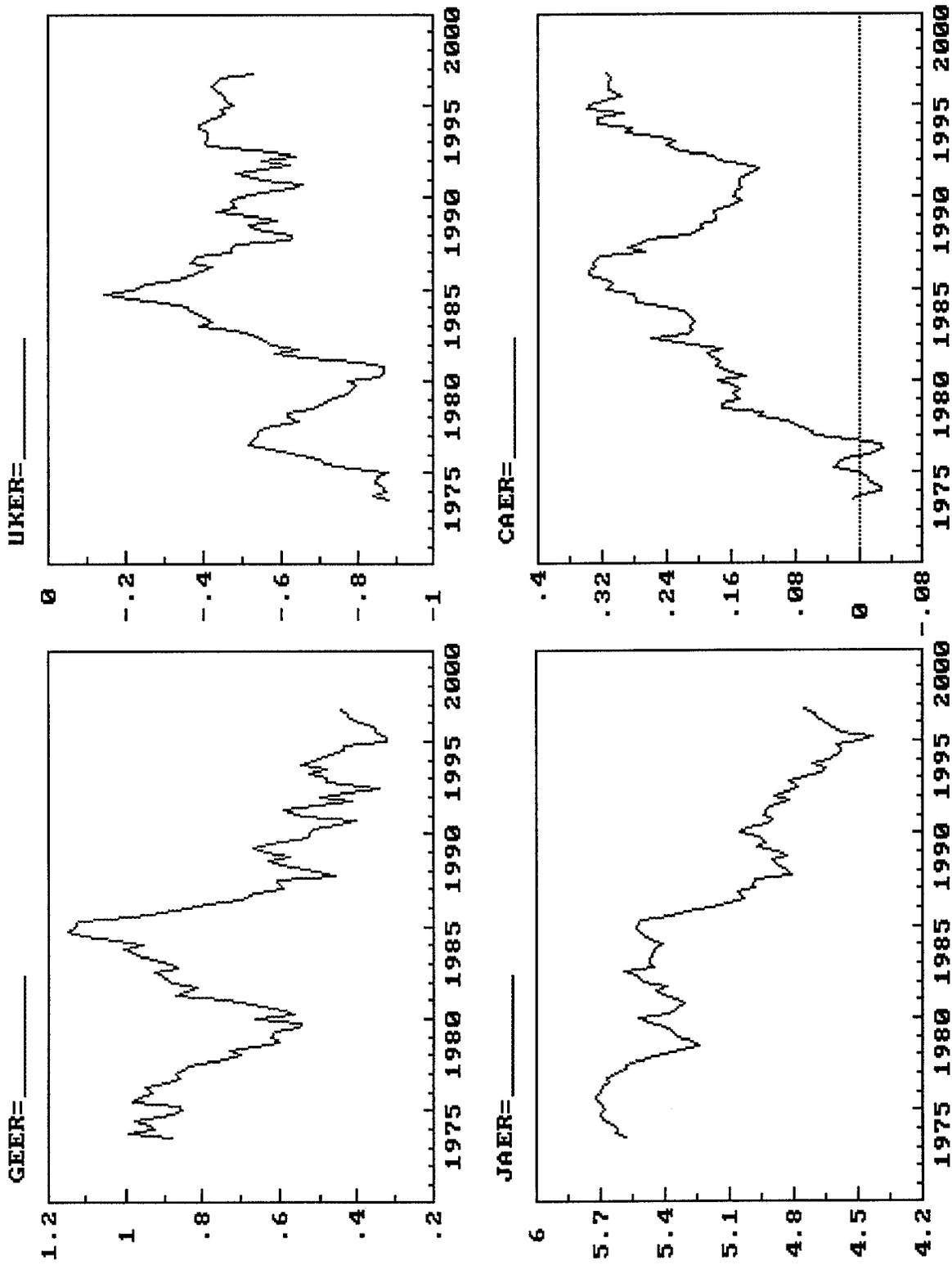
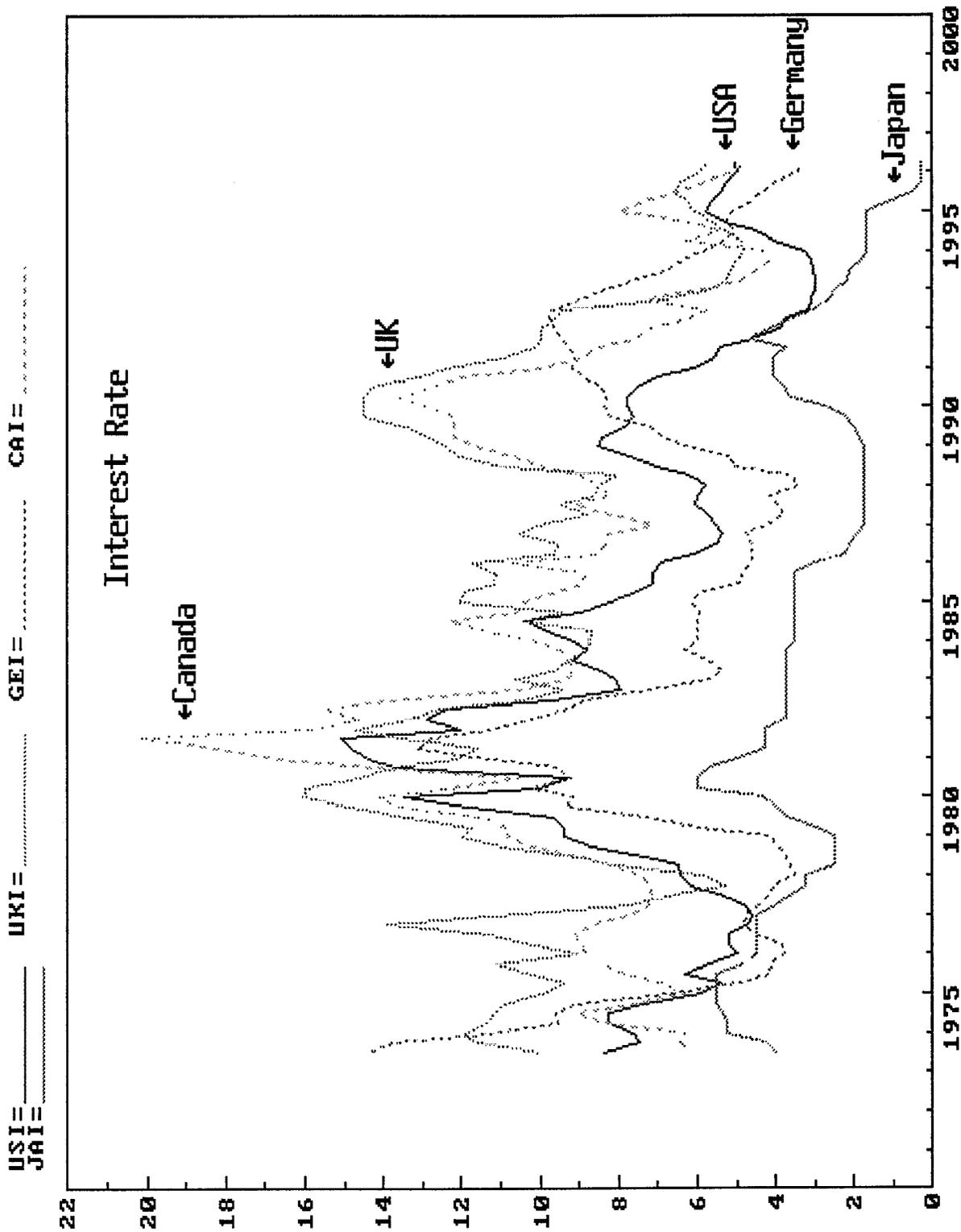


Figure 2. Interest Rates (in percentages)



## Inflation

There are two distinct periods for inflation (see Figure 3). In general, after 1991 inflation is lower in most of the countries, except for Germany. However, with average inflation levels differing, stable inflation is not achieved synchronously by all countries. Notably, Japan has the lowest inflation rate among the five countries studied.

## Current account balances

Movements in current account balances exhibit a great deal of idiosyncrasy among the countries studied (see Figure 4). For the United States, current account balances fell to a deficit in 1982, and quarterly data since then has seldom shown a surplus. On the other hand, the United Kingdom's current account turned to a deficit in 1987, and has barely managed to realize a surplus since then. A similar picture is true for Canada. Germany's (or West Germany's) current account surplus was steadily increasing during 1984–90. However, after reunification Germany's current account turned sharply downward into a deficit and has not recovered since then. Japan is the only country among those surveyed that has been able to maintain large current account surplus during most of the period.

In terms of volatility, Table 1 shows that the exchange rate series have on average a larger standard deviation than that of the interest rate series. This is shown more dramatically by changes in interest rate differentials and in exchange rates. Clearly changes in exchange rates dwarfed changes in interest rate differential (see Figure 5).

## B. Unit Root and Cointegration Study

The results for unit root tests on the variables are summarized in Table 2. Almost all series are non-stationary. Unit root results show that exchange rates, output, inflation, and interest rates should be treated as  $I(1)$  variables.

Next cointegration tests were performed using procedures proposed by Johansen (1988). Since the Johansen procedure is now well known, a brief explanation should suffice.

Consider a fully endogenized dynamic system containing endogenous variables  $y$ :

$$y_t = \sum_{i=1}^m \pi_i y_{t-i} + v_t, \quad v_t \sim IN(0, \Omega) \quad (9)$$

with  $y_t$  ( $n \times 1$ ). When the data  $\{y_t\}$  are  $I(1)$ , a useful reformulation of the system to *error correction form* (see Hendry, Pagan, and Sargan (1984), Eagle and Granger (1987) and Johansen (1988)) is:

Figure 3. Inflation (quarterly changes of CPI in logs, mean adjusted)

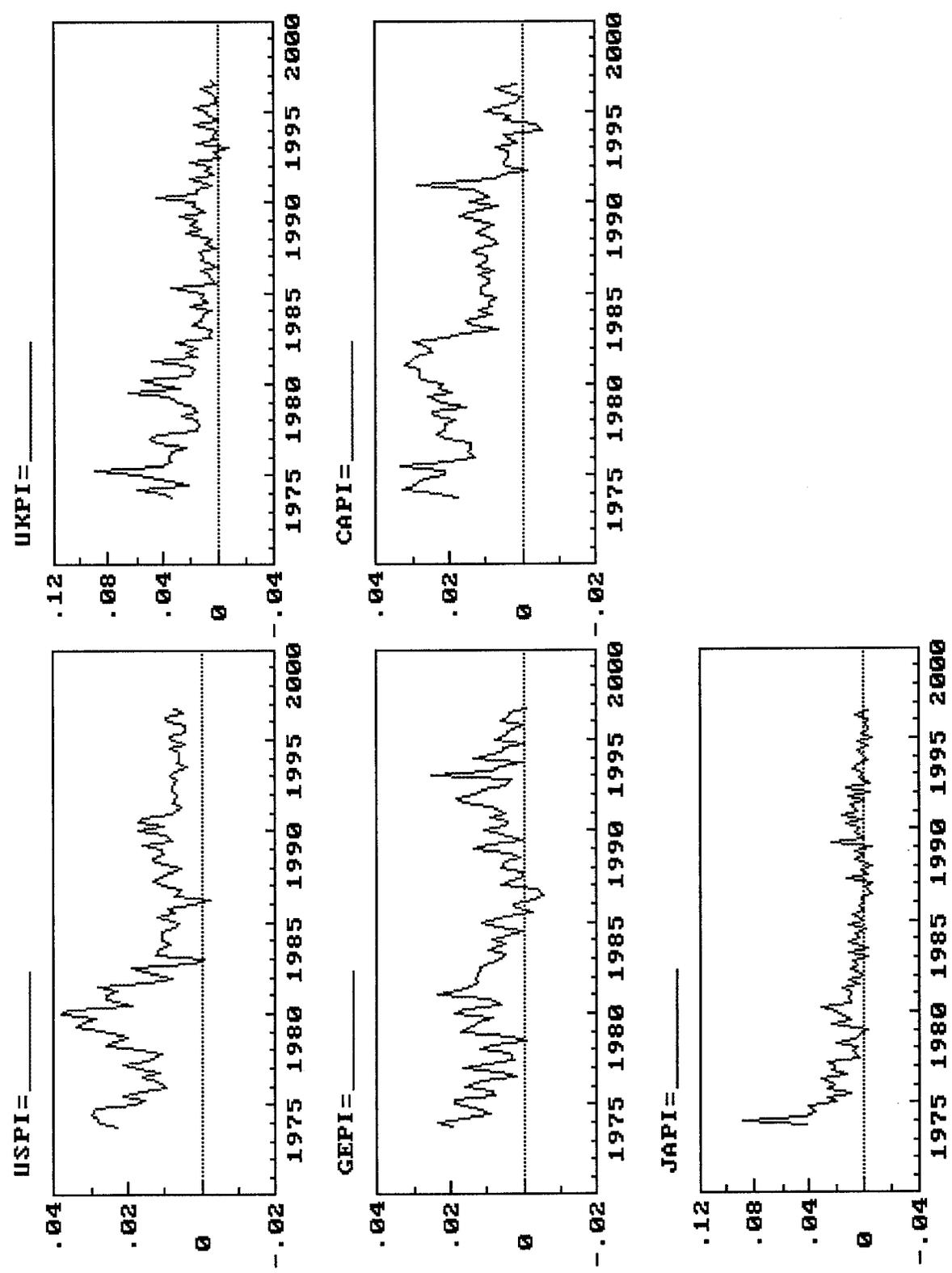
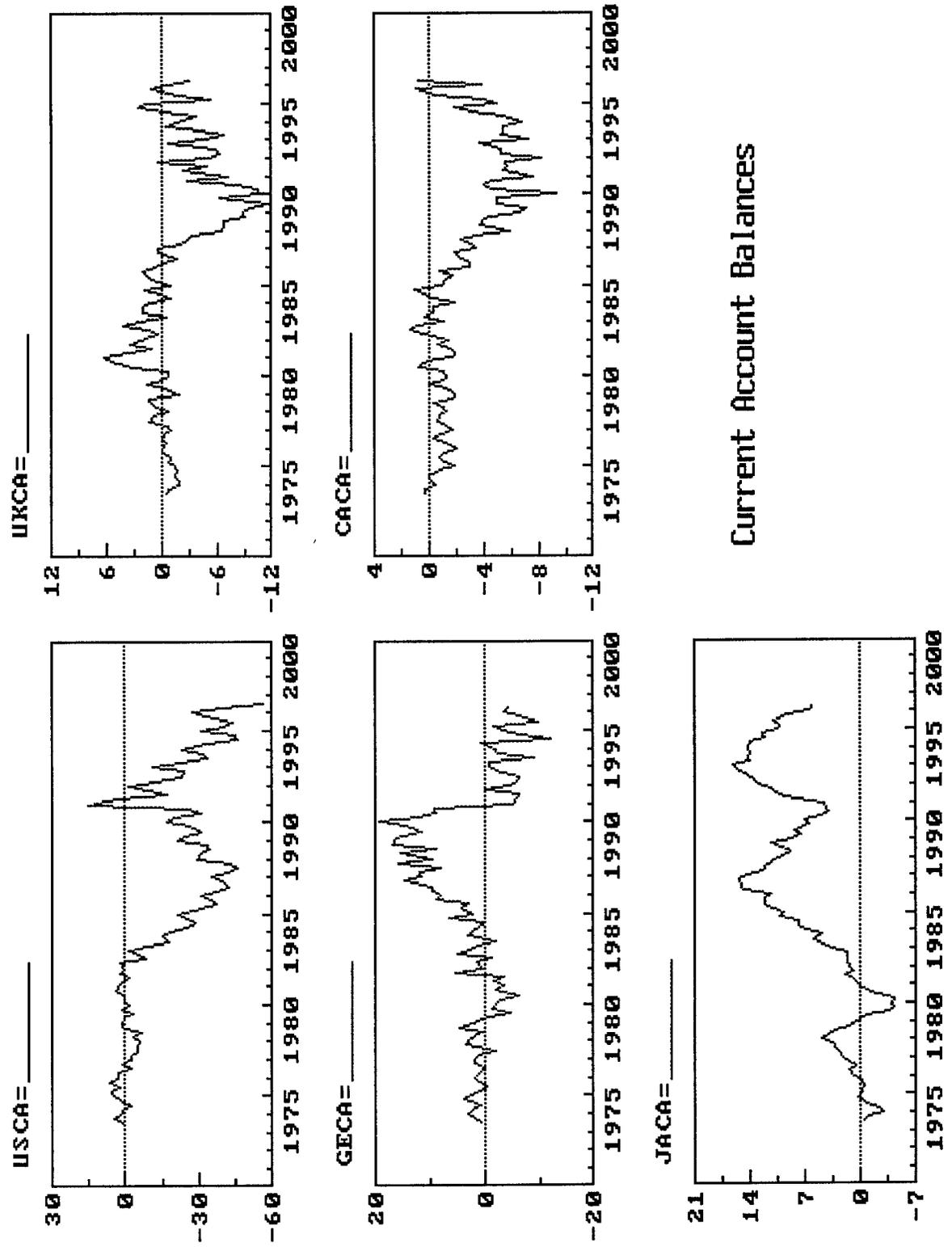


Figure 4. Current Account Balances



Current Account Balances

Figure 5. Interest Differential and Changes in Exchange Rates

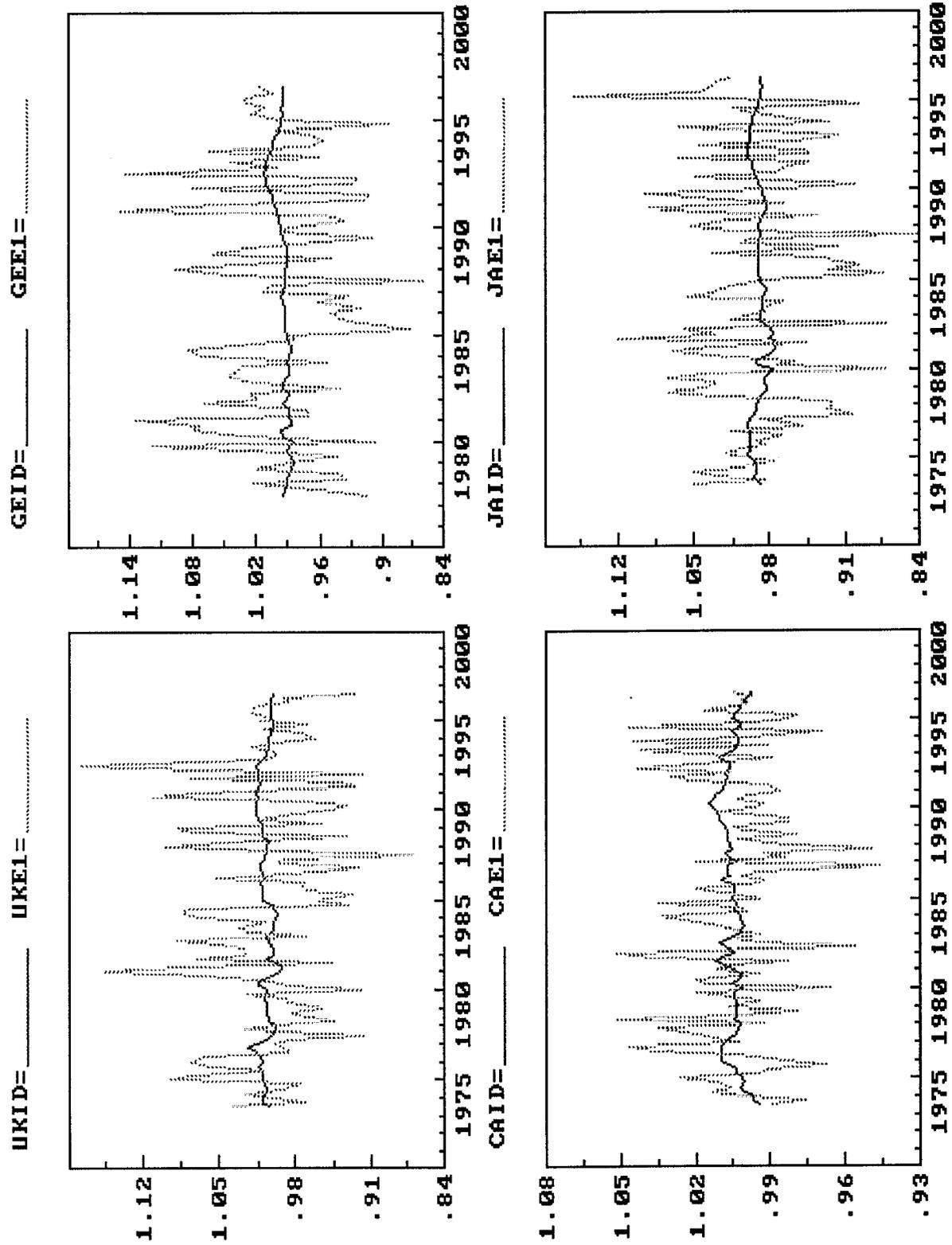


Table 2. Unit Root Tests

|      | t-adf   | $\beta$ Y <sub>-1</sub> | $\sigma$ | lag | t-DY <sub>lag</sub> | t-prob | F-prob |
|------|---------|-------------------------|----------|-----|---------------------|--------|--------|
| USI  | -2.451  | 0.914                   | 0.835    | 5   | 3.434               | 0.001  | 0.365  |
| UKI  | -2.302  | 0.897                   | 1.152    | 1   | 2.787               | 0.006  | 0.999  |
| GEI  | -2.287  | 0.935                   | 0.607    | 1   | 6.000               | 0.000  | 0.152  |
| CAI  | -2.157  | 0.908                   | 1.195    | 1   | 2.354               | 0.020  | 0.236  |
| JAI  | -1.771  | 0.947                   | 0.342    | 1   | 3.844               | 0.000  | 0.718  |
| USPI | -1.797  | 0.880                   | 0.004    | 2   | -5.084              | 0.000  | 0.239  |
| UKPI | -2.607  | 0.763                   | 0.011    | 4   | 2.355               | 0.021  | 0.408  |
| GEPI | -1.926  | 0.775                   | 0.004    | 3   | -4.785              | 0.000  | 0.338  |
| CAPI | -1.850  | 0.874                   | 0.005    | 2   | -2.095              | 0.039  | 0.494  |
| JAPI | -3.384* | 0.710                   | 0.005    | 3   | -5.617              | 0.000  | 0.236  |
| UKER | -2.842  | 0.893                   | 0.052    | 3   | 2.837               | 0.005  | 0.733  |
| GEER | -1.777  | 0.941                   | 0.061    | 4   | 1.872               | 0.064  | 0.599  |
| CAER | -1.815  | 0.955                   | 0.021    | 3   | 2.612               | 0.010  | 0.980  |
| JAER | -1.090  | 0.979                   | 0.060    | 5   | -1.791              | 0.077  | 0.295  |
| USCA | -1.587  | 0.936                   | 5.608    | 4   | 4.876               | 0.000  | 0.519  |
| UKCA | -1.750  | 0.887                   | 1.978    | 4   | 3.646               | 0.001  | 0.262  |
| GECA | -1.738  | 0.898                   | 3.171    | 4   | 4.753               | 0.000  | 0.245  |
| CACA | -1.206  | 0.930                   | 1146.0   | 4   | 4.380               | 0.000  | 0.645  |
| JACA | -1.614  | 0.958                   | 1.319    | 1   | 1.867               | 0.065  | 0.291  |

Unit root tests 1975 (2) to 1996 (2)

Critical values: 5%=-2.895 1%=-3.508; Constant included

|       | t-adf  | $\beta$ Y <sub>-1</sub> | $\sigma$ | lag | t-DY <sub>lag</sub> | t-prob | F-prob |
|-------|--------|-------------------------|----------|-----|---------------------|--------|--------|
| USGDP | -2.568 | 0.904                   | 0.008    | 1   | 3.735               | 0.000  | 0.708  |
| UKGDP | -2.582 | 0.921                   | 0.008    | 3   | 2.673               | 0.009  | 0.700  |
| GEGDP | -2.138 | 0.922                   | 0.006    | 4   | 2.296               | 0.024  | 0.562  |
| CAGDP | -2.132 | 0.947                   | 0.007    | 1   | 5.043               | 0.000  | 0.880  |
| JAGDP | -1.194 | 0.964                   | 0.006    | 4   | 2.201               | 0.030  | 0.607  |

Unit root tests 1975 (1) to 1996 (3)

Critical values: 5%=-3.461 1%=-4.066; Constant and Trend included

Note: The tests conducted are ADF test: (depending on whether trend is included or not)

$$\Delta Y_t = \alpha + \mu t + (\beta - 1)Y_{t-1} + \sum \gamma_i \Delta Y_{t-i} + \epsilon_t$$

Critical values are based on response surfaces in MacKinnon (1991), t-adf is the t-value for  $Y_{t-1}$  in the regression,  $\beta$   $Y_{t-1}$  is the coefficient of  $Y_{t-1}$  in a level regression,  $\sigma$  is the standard error of the equation, lag is the number of lags used in the regression, t-DY<sub>lag</sub> is the t value for the last lag in the regression, and F-prob is the probability that higher lags are not significant.

$$\Delta y_t = \sum_{i=1}^{m-1} \delta_i \Delta y_{t-i} + P y_{t-1} + v_t \quad (10)$$

Clearly  $P$  cannot be full rank since that would contradict the assumption that  $\{y_t\}$  are  $I(1)$ , so let  $r(P) = p < n$ . Then  $P = \alpha\beta'$  where  $\alpha$  and  $\beta$  are  $n \times p$  matrices of rank  $p$ , and  $\beta'y_t$  must comprise  $p$  cointegrating  $I(0)$  relations inducing the restricted  $I(0)$  representation:

$$\Delta y_t = \sum_{i=1}^{m-1} \delta_i \Delta y_{t-i} + \alpha(\beta'y_{t-1}) + v_t \quad (11)$$

The test of the hypothesis that  $r(P) = p < n$  is carried out by the trace and maximum eigenvalue statistics for  $P$ .

Cointegration test is done bilaterally for each country together with the United States. The results are presented in Table 3.

In addition, the following hypotheses were tested: (a) none of the cointegration relationship affects exchange rates, (b) exchange rates do not enter into all the cointegration relations; and the joint hypothesis of (a) and (b). Hypothesis (a), if true, would indicate that there is no long-run impact of other variables on exchange rates, and hypothesis (b) assumes that exchange rates do not affect other variables in the long run. In system (12), similar hypotheses of say,  $y_1$ , can be expressed as:

$$\begin{aligned} H_a: \alpha_{ij} &= 0, \quad i=1, \dots, n. \\ H_b: \beta_{1j} &= 0, \quad j=1, \dots, p. \end{aligned} \quad (12)$$

Results are included in Table 3. All the results reject the hypothesis that no cointegration exists among the variables, and usually show evidence of multiple cointegration relationships. For example, in the case of the United States and Germany, the hypothesis of eight cointegration relationships is not rejected. More importantly, all hypotheses which were proposed regarding exchange rates were rejected decisively. This confirms the theoretical conclusion that other economic variables affect exchange rates, although exchange rates also impact on other variables in the long run.

Table 3. Cointegration Results

**U.S./GERMANY**

| H0:rank=p | -Tlog(1-μ) | using T-nm | 95%  | -Σlog(1-μ) | using T-nm | 95%   |
|-----------|------------|------------|------|------------|------------|-------|
| p = 0     | 127.9**    | 30.83      | 57.1 | 487.8**    | 117.5      | 192.9 |
| p <= 1    | 93.4**     | 22.51      | 51.4 | 359.8**    | 86.71      | 156.0 |
| p <= 2    | 76.17**    | 18.35      | 45.3 | 266.4**    | 64.2       | 124.2 |
| p <= 3    | 55.88**    | 13.47      | 39.4 | 190.3**    | 45.85      | 94.2  |
| p <= 4    | 48.19**    | 11.61      | 33.5 | 134.4**    | 32.38      | 68.5  |
| p <= 5    | 33.26**    | 8.015      | 27.1 | 86.2**     | 20.77      | 47.2  |
| p <= 6    | 30.95**    | 7.458      | 21.0 | 52.93**    | 12.76      | 29.7  |
| p <= 7    | 19.26**    | 4.641      | 14.1 | 21.98**    | 5.297      | 15.4  |
| p <= 8    | 2.72       | 0.65       | 3.8  | 2.72       | 0.65       | 3.8   |

Sample period: 1975 (4) to 1996 (2)

Number of lags used in the analysis: 7

Vector portmanteau 9 lags = 928.33

Vector AR 1-1 F(81, 21) = 0.94

Vector normality Chi<sup>2</sup>(18) = 23.851

H<sub>a</sub>: LR-test, rank=8: Chi<sup>2</sup>( 8) = 119.98 \*\*

H<sub>b</sub>: LR-test, rank=8: Chi<sup>2</sup>( 8) = 67.71 \*\*

Joint[H<sub>a</sub> and H<sub>b</sub>]: LR-test, rank=8: Chi<sup>2</sup>(16) = 106.44 \*\*

**U.S./JAPAN**

| H0:rank=p | -Tlog(1-μ) | using T-nm | 95%  | -Σlog(1-μ) | using T-nm | 95%   |
|-----------|------------|------------|------|------------|------------|-------|
| p == 0    | 338.3**    | 44.83      | 57.1 | 1174.0**   | 155.6      | 192.9 |
| p <= 1    | 291.5**    | 38.63      | 51.4 | 835.6**    | 110.7      | 156.0 |
| p <= 2    | 200.4**    | 26.55      | 45.3 | 544.1**    | 72.12      | 124.2 |
| p <= 3    | 115.1**    | 15.25      | 39.4 | 343.8**    | 45.56      | 94.2  |
| p <= 4    | 91.37**    | 12.11      | 33.5 | 228.7**    | 30.31      | 68.5  |
| p <= 5    | 69.36**    | 9.192      | 27.1 | 137.4**    | 18.21      | 47.2  |
| p <= 6    | 40.51**    | 5.368      | 21.0 | 68.01**    | 9.013      | 29.7  |
| p <= 7    | 25.08**    | 3.324      | 14.1 | 27.5**     | 3.644      | 15.4  |
| p <= 8    | 2.419      | 0.32       | 3.8  | 2.419      | 0.32       | 3.8   |

Sample period: 1975 (4) to 1996 (2)

Number of lags used in the analysis: 8

Vector portmanteau 9 lags = 1599.1

Vector normality Chi<sup>2</sup>(18) = 12.26

H<sub>a</sub>: LR-test, rank=8: Chi<sup>2</sup>( 8) = 49.72 \*\*

H<sub>b</sub>: LR-test, rank=8: Chi<sup>2</sup>( 8) = 272.81 \*\*

Joint[H<sub>a</sub> and H<sub>b</sub>]: LR-test, rank=8: Chi<sup>2</sup>(16) = 311.87 \*\*

Table 3. Cointegration Results (concluded)

**U.S./U.K.**

| H0:rank=p | -Tlog(1-μ) | using T-nm | 95%  | -Σlog(1-μ) | using T-nm | 95%   |
|-----------|------------|------------|------|------------|------------|-------|
| p = 0     | 447.5**    | 59.31*     | 57.1 | 1,580.0**  | 209.4**    | 192.9 |
| p ≤ 1     | 310.5**    | 41.15      | 51.4 | 1,132.0**  | 150.1      | 156.0 |
| p ≤ 2     | 296.3**    | 39.26      | 45.3 | 821.8**    | 108.9      | 124.2 |
| p ≤ 3     | 252.5**    | 33.46      | 39.4 | 525.5**    | 69.65      | 94.2  |
| p ≤ 4     | 123.6**    | 16.38      | 33.5 | 273.0**    | 36.18      | 68.5  |
| p ≤ 5     | 74.96**    | 9.935      | 27.1 | 149.4**    | 19.8       | 47.2  |
| p ≤ 6     | 42.94**    | 5.69       | 21.0 | 74.48**    | 9.87       | 29.7  |
| p ≤ 7     | 30.2**     | 4.003      | 14.1 | 31.54**    | 4.18       | 15.4  |
| p ≤ 8     | 1.33       | 0.18       | 3.8  | 1.33       | 0.17       | 3.8   |

Sample period: 1975 (4) to 1996 (2)

Number of lags used in the analysis: 8

Vector portmanteau 9 lags = 1596.2

Vector normality Chi<sup>2</sup>(18) = 47.305 \*\*

H<sub>a</sub>: LR-test, rank=8: Chi<sup>2</sup>( 8) = 354.68 \*\*

H<sub>b</sub>: LR-test, rank=8: Chi<sup>2</sup>( 8) = 537.02 \*\*

Joint[H<sub>a</sub> and H<sub>b</sub>]: LR-test, rank=8: Chi<sup>2</sup>(16) = 587.83 \*\*

**U.S./CANADA**

| H0:rank=p | -Tlog(1-μ) | using T-nm | 95%  | -Σlog (1-μ) | using T-nm | 95%   |
|-----------|------------|------------|------|-------------|------------|-------|
| p == 0    | 155.1**    | 37.36      | 57.1 | 524.7**     | 126.4      | 192.9 |
| p ≤ 1     | 89.53**    | 21.57      | 51.4 | 369.6**     | 89.06      | 156.0 |
| p ≤ 2     | 81.64**    | 19.67      | 45.3 | 280.1**     | 67.49      | 124.2 |
| p ≤ 3     | 73.58**    | 17.73      | 39.4 | 198.4**     | 47.81      | 94.2  |
| p ≤ 4     | 43.6**     | 10.51      | 33.5 | 124.9**     | 30.08      | 68.5  |
| p ≤ 5     | 38.77**    | 9.342      | 27.1 | 81.25**     | 19.58      | 47.2  |
| p ≤ 6     | 23.33*     | 5.623      | 21.0 | 42.48**     | 10.24      | 29.7  |
| p ≤ 7     | 19.08**    | 4.597      | 14.1 | 19.15*      | 4.614      | 15.4  |
| p ≤ 8     | 0.068      | 0.0167     | 3.8  | 0.069       | 0.017      | 3.8   |

Sample period: 1975 (4) to 1996 (2)

Number of lags used in the analysis: 7

Vector portmanteau 9 lags = 938.81

Vector AR 1-1 F(81, 21) = 0.77

Vector normality Chi<sup>2</sup>(18) = 13.845

H<sub>a</sub>: LR-test, rank=8: Chi<sup>2</sup>( 8) = 116.84 \*\*

H<sub>b</sub>: LR-test, rank=8: Chi<sup>2</sup>( 8) = 89.071 \*\*

Joint[H<sub>a</sub> and H<sub>b</sub>]: LR-test, rank=8: Chi<sup>2</sup>(16) = 183.82 \*\*

#### IV. SINGLE-EQUATION ESTIMATION

The results of cointegration exercises show the existence of structural long-run relationships between bilateral exchange rates and bilateral economic fundamentals. However, given that there are multiple cointegrating relationships affecting exchange rate movements, the interpretation and the use of such relationships is not straightforward. Single-equation estimation is used to examine the exchange rate movements and the relationship with other economic variables in more detail.

The estimation starts with the following unrestricted form:

$$e_t = \sum_{i=1}^n \alpha_i e_{t-i} + \sum_{i=0}^n \beta_i z_{t-i} + \epsilon_t \quad (13)$$

where  $e_t$  is the exchange rate and  $z_t$  is a vector of independent variables. Consistent with the above discussion, these variables include inflation, output, interest rates, and current account balances. The estimates of (13) provide a benchmark “statistical model” against which individual specifications can be compared. We start with appropriate lag selection for model (13) so that residuals exhibit satisfactory properties, ideally, white noise, and that the model appears to be reasonably stable. Then we do model reduction to achieve a more parsimonious and balanced  $I(0)$  presentation. The results for the deutsche mark and Japanese yen are reported as follows.

##### A. Deutsche Mark/U.S. Dollar

Summary statistics are presented below for modeling the deutsche mark/dollar exchange rate (GEER), for the estimation period 1975Q2 to 1993Q2 and out of sample forecast period 1993Q3 to 1996Q2. A lag of 6 is selected for estimating model (13).

$R^2 = 0.992$   $F(62, 10) = 21.143$  [0.00]  $\sigma = 0.047$   $DW = 2.33$   
 $RSS = 0.022$  for 63 variables and 73 observations

| Test of Residuals                     | Tests of Parameter Constancy               |
|---------------------------------------|--|
| AR 1- 5F(5, 5) = 5.04                 | Forecast Chi <sup>2</sup> (12) = 1538.1 ** |
| ARCH 4 F(4, 2) = 0.057                | Chow F(12, 10) = 1.68                      |
| Normality Chi <sup>2</sup> (2) = 3.46 |  |
| RESET F(1, 9) = 1.16                  | (** denotes significance at 1% level)      |

Tests for regression residuals show that they are consistent with  $\epsilon_t$  being white noise, and the model appears to be constant in the forecast period.

Next model (13) is simplified by reparameterizing any short distributed lags and deleting inessential variables such that the overall F-test of all the restrictions is not significant at 0.05 confidence level. In the process, a long-run relation for the exchange rate is identified as:

$$\begin{aligned} \text{GEER} = & 0.051 \text{ USI} - 7.81 \text{ USPI} + 35.98 \text{ GEPI} + 1.17 \text{ USGDP} - 3.64 \text{ GEGDP} \\ (\text{SE}) & (0.014) \quad (4.07) \quad (8.51) \quad (0.437) \quad (1.32) \end{aligned}$$

Standard errors are reported in parenthesis. The variables are all significant, and signs of the coefficients are consistent with theory. Briefly summarizing the results: high U.S. interest rates, U.S. output, and German inflation will cause the dollar to appreciate against the deutsche mark in the long run, whereas high U.S. inflation and German output will cause the deutsche mark to appreciate against the dollar in the long run. Current account variables are not significant in the long run.<sup>3</sup>

The final tested down model represented in difference and error correction form, was estimated as follows:

$$\begin{aligned} \text{DGEER} = & +1.64 \text{ USGDP0\_2} + 0.60 \text{ USGDP3\_6} - 3.376 \text{ GEPI1\_4} - 0.127 \text{ ECMG\_1} - 0.064 \text{ ECMG\_5} \\ [\text{HCSE}] & \quad [0.43] \quad [0.29] \quad [1.10] \quad [0.03] \quad [0.03] \end{aligned} \quad (14)$$

$$R^2 = 0.36 \quad \sigma = 0.053 \quad \text{DW} = 1.90$$

RSS = 0.20 for 5 variables and 73 observations

Heteroscedastic-consistent standard errors are reported in brackets.

Tests of model reduction

$$\text{Model 13} \rightarrow \text{14: } F(58, 11) = 1.52$$

#### Test of Residuals

$$\begin{aligned} \text{AR 1-5} F(5, 64) &= 0.78 \\ \text{ARCH 4} F(4, 61) &= 1.08 \\ \text{Normality} \text{ Chi}^2(2) &= 2.32 \\ \text{Xi}^2 F(10, 58) &= 0.56 \\ \text{Xi} \cdot \text{Xj} F(20, 48) &= 0.63 \\ \text{RESET} F(1, 68) &= 0.09 \end{aligned}$$

#### Tests of Parameter Constancy

$$\begin{aligned} \text{Forecast} \text{ Chi}^2(12) &= 12.87 \\ \text{Chow} F(12, 69) &= 1.01 \\ t(11) \text{ for a zero forecast innovation mean} &= 1.03 \end{aligned}$$

---

<sup>3</sup>We also examined the sensitivity of the result to alternative measures of the current account, including the ratio of the current account to GDP and the cumulative current account balance as a possible measure of country specific risk premium. However, these variables were also insignificant.

Among the independent variables, ECMG denotes the deviation of the exchange rate from its long-run level defined above, and all other variables are differences of respective lags denoted by numbers after the variable name. For example, GEPI1\_4 is the difference of first lag of GEPI with respect to the fourth lag of GEPI.

Tests on residuals are all satisfactory. The test on model reduction is not significant which shows that model (14) is a parsimonious representation of (13).

The recursive estimation of model (14) also shows satisfactory results as can be seen in Figures 6 and 7. The recursively estimated coefficients and one-step-ahead forecast residuals and recursive structural break tests all appear to indicate a stable system. Stability is also confirmed by the parameter constancy test performed on the forecasts. Figure 8 demonstrates that the one-step-ahead forecasts of the system is not unreasonable. Most of the actual outcomes are within the 95 percent confidence intervals.

Next a “horse race” is run for model (14) against a simple random walk (with drift) model. When comparing the properties of two competing models, the appropriate selection criteria should be based on two aspects. The first concerns the forecast performance of the competing models. The selection criteria is forecast encompassing. (See Chong and Hendry (1986), Ericsson (1992)). The test is undertaken using the following regression:

$$(y_t - \hat{y}_{1t}) = \alpha \bar{y}_{2t} + v_t \quad (15)$$

where the dependent variable is the forecast error from model 1 and the independent variable is the forecast from model 2. Testing that model 2 does not forecast encompass model (1) is equivalent to testing  $\alpha = 0$ . To test the hypothesis that the random walk model does not forecast encompass model (14), a regression of the one-step-ahead forecast error of model (14) is run against the forecast of the random walk. The latter forecast is a constant.

The second test concerns the power to explain the data within sample (see Hendry and Richard (1982), (1989), Mizon (1984), and Mizon and Richard (1986)). For this purpose, various encompassing tests can be performed on the two competing models.

Figure 6. Recursive Estimation for Deutsche Mark/U.S. Dollar, Coefficients

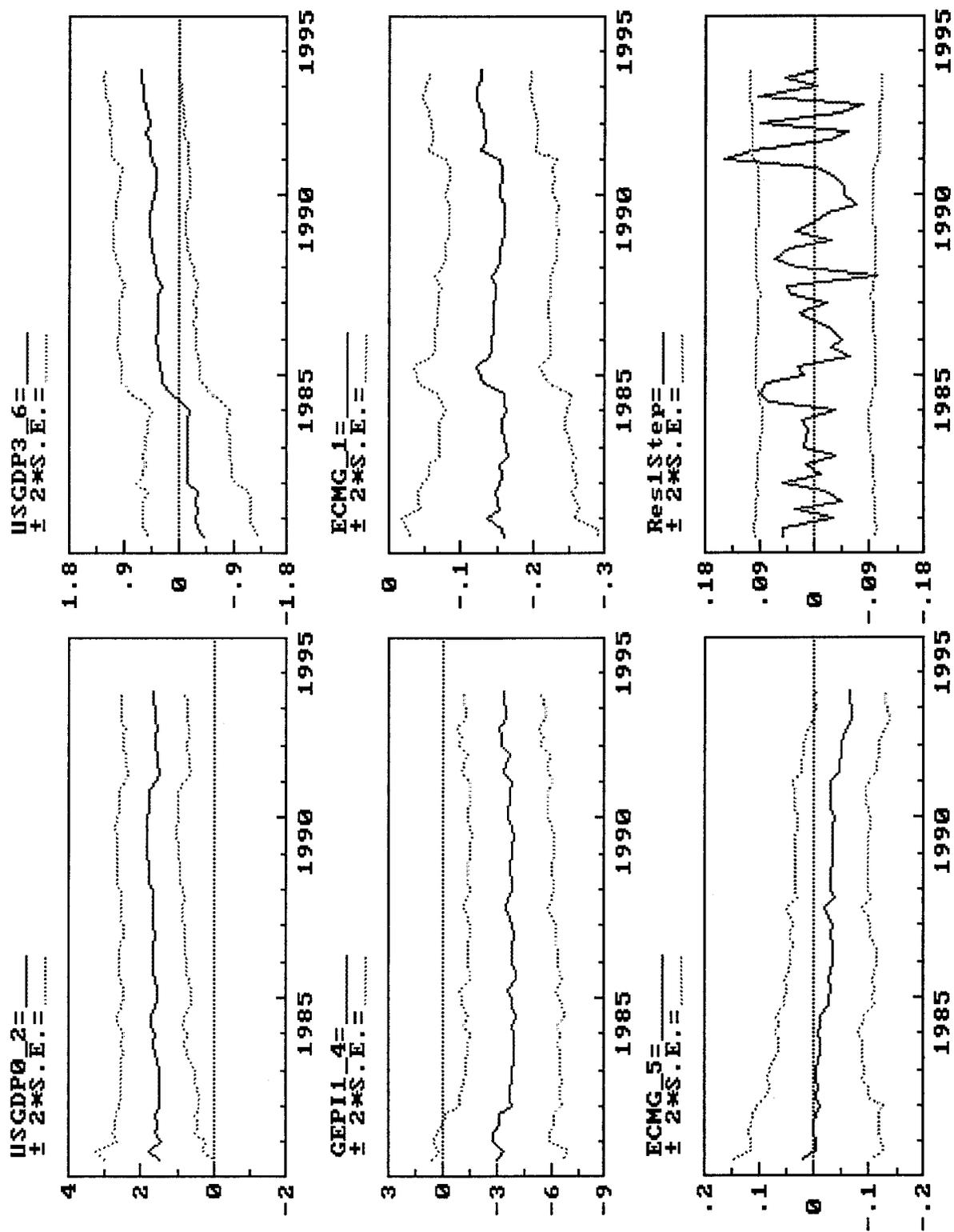


Figure 7. Recursive Estimation Results for Deutsche Mark/U.S. Dollar, Parameter Constancy

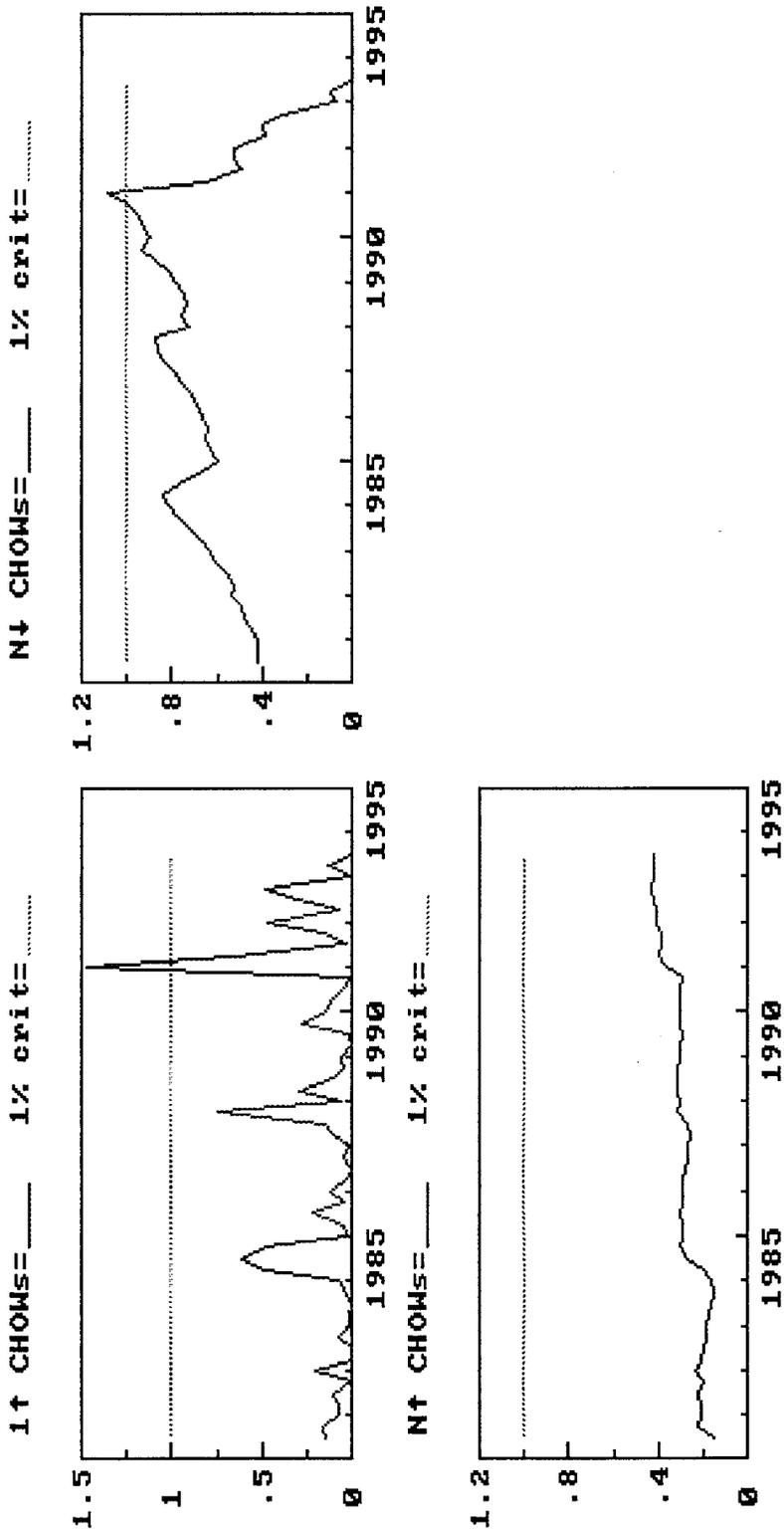
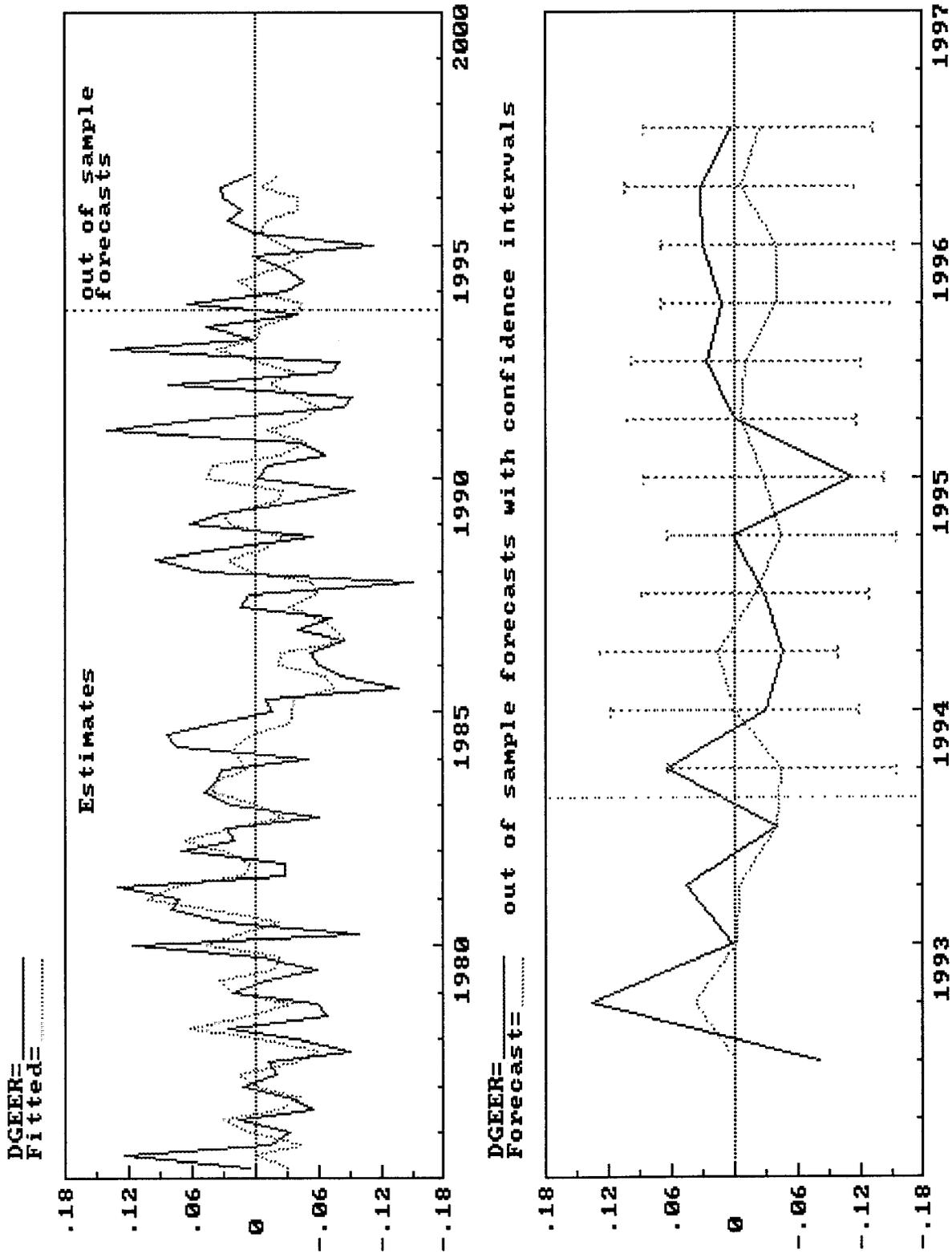


Figure 8. Fitted and Forecast Results for Deutsche Mark/U.S. Dollar



The results for both encompassing tests are presented in Table 4. The results show that the hypothesis of the random walk model encompassing model (14) is not accepted, whereas the hypothesis of model (14) encompassing the random walk model is accepted.

### B. Japanese Yen/U.S. Dollar

The results for Japanese yen/U.S. dollar exchange rates are now briefly examined. The estimation period is: 1975Q2 to 1993Q2 and out of sample forecast period 1993Q3 to 1996Q2. The summary statistics for the general, unrestricted model are:

$$R^2 = 0.995 \quad F(62, 10) = 34.596 [0.00] \quad \sigma = 0.055 \quad DW = 2.75 \quad (16)$$

RSS = 0.0307 for 63 variables and 73 observations

| Test of Residuals                     | Tests of Parameter Constancy              |
|---------------------------------------|---|
| AR 1- 5F(5, 5) = 2.23                 | Forecast Chi <sup>2</sup> (12) = 91.94 ** |
| ARCH 4 F(4, 2) = 0.033                | Chow F(12, 10) = 1.30                     |
| Normality Chi <sup>2</sup> (2) = 0.28 |   |
| RESET F(1, 9) = 0.29                  |   |

The estimation of model (16) yields satisfactory residuals with six lags. After simplification, the following model can be derived in difference and error correction form:

$$DJAER = -0.37 ECMJ_{-1} - 1.41 JAGDP3_{-6} + 1.73 USGDP2_{-6} + 0.002 USCA1_{-5} - 0.012 USI1_{-5} + 0.18 JAER1_{-5} \quad (17)$$

[HCSE] [0.05] [0.37] [0.36] [0.001] [0.004] [0.042]

$$R^2 = 0.44 \quad \sigma = 0.049 \quad DW = 2.12$$

RSS = 0.16 for 6 variables and 73 observations

Test of model reduction  
 Model 16 → 17: F(57, 11) = 0.81

| Test of Residuals                     | Tests of parameter constancy                     |
|---------------------------------------|--|
| AR 1- 5F(5, 62) = 0.81                | Forecast Chi <sup>2</sup> (12) = 16.33           |
| ARCH 4 F(4, 59) = 0.35                | Chow F(12, 67) = 1.34                            |
| Normality Chi <sup>2</sup> (2) = 1.75 | t(11) for a zero forecast innovation mean = 0.12 |
| Xi <sup>2</sup> F(11, 55) = 0.62      |  |
| Xi*Xj F(25, 41) = 0.39                |  |
| RESET F(1, 66) = 0.79                 |  |

Table 4. Deutsche Mark/U.S. Dollar: Encompassing Results Comparing the Model Estimate and Random Walk Model

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**Forecast Encompassing**

Dependent variable: Forecast error from model (14)

Explanatory variable: forecast from random walk model

The present sample is: 1993 (3) to 1996 (3)

| Variable | Coefficient | Std.Error | t-value | t-prob | PartR <sup>2</sup> |
|----------|-------------|-----------|---------|--------|--------------------|
| Constant | 0.0153376   | 0.015     | 1.04    | 0.32   | 0.082              |

R<sup>2</sup> = 0    $\sigma$  = 0.0534   DW = 1.96

RSS = 0.0342 for 1 variables and 13 observations

The test that the coefficient on the explanatory variable is zero is significant at 1% level.

**Model Encompassing**

Encompassing test statistics

The present sample is: 1975 (2) to 1993 (3)

Model 1 = Model (15)

Model 2 = Random walk

$\sigma_1 = 0.054$     $\sigma_2 = 0.065$     $\sigma[\text{Joint}] = 0.054$

| Test        | Form                 | Model 1 v Model 2 | Form                 | Model 2 v Model 1 |
|-------------|----------------------|-------------------|----------------------|-------------------|
| Cox         | N(0,1)               | 0.54              | N(0,1)               | -50.72            |
| Ericsson IV | N(0,1)               | -0.52             | N(0,1)               | 40.62             |
| Sargan      | Chi <sup>2</sup> (1) | 0.39              | Chi <sup>2</sup> (5) | 26.45             |
| Joint Model | F(1,68)              | 0.39              | F(5,68)              | 7.73              |

---

The long-run relationship is identified as:

$$\begin{array}{rcccccc} \text{JAER} = & +21.02 & - 0.58 & \text{JAGDP} & - 1.04 & \text{USGDP} & + 0.046 & \text{USI} & - 8.226 & \text{USPI} & + 0.054 & \text{JAI} \\ (\text{SE}) & (1.451) & & (0.63) & & (1.052) & & (0.008) & & (2.84) & & (0.02) \end{array}$$

In the long-run relationship the signs on USGDP and Japanese interest rates differ from what theory would predict but the signs on the other variables are as expected. The U.S. current account variables are found to be significant in the short run, but not in the long run.<sup>4</sup> This contrasts with the deutsche mark/U.S. dollar case where current account variables were not found significant even in the short run.

Recursive estimation for the model also yields satisfactory results (see Figures 9 and 10). The one-step-ahead forecasts of the system is also reasonably satisfactory (see Figure 11). The test of model reduction is not significant.

Again we study the encompassing properties of model (17) against the simple random walk with drift model. The results are presented in Table 5. As in case of the deutsche mark, the analysis supports the finding that model (17) encompasses the simple random walk model both in terms of forecasting and explanatory power.

## V. CONCLUSION

The empirical results presented above lead to a number of conclusions about exchange rate determination:

First, the results of the empirical analysis indicate that bilateral nominal exchange rates can be reasonably explained by bilateral economic fundamentals such as output, inflation and interest rates. The single-equation estimates presented encompass the random walk models and evidence stability in out of sample forecast tests. These results therefore contradict the "perceived wisdom" that exchange rates are random walks and cannot be modeled.

Second, the model and empirical estimates illustrate the role of cyclical and longer-term monetary factors in exchange rate determination. In the context of high capital mobility and low sovereign risks the exchange rates of the major industrial countries are determined in the longer-run primarily by factors consistent with a monetary approach. Current account balances do not affect the long-run level of the exchange rate, although they impact on the short-run dynamics of exchange rate movements in the case of the Japanese yen/U.S. dollar exchange rate.

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<sup>4</sup>The use of the current account to GDP ratio and the cumulative current account were both insignificant and did not improve the long-run properties of the equation.

Figure 9. Recursive Estimation Results for Japanese Yen/U.S. Dollar, Coefficients

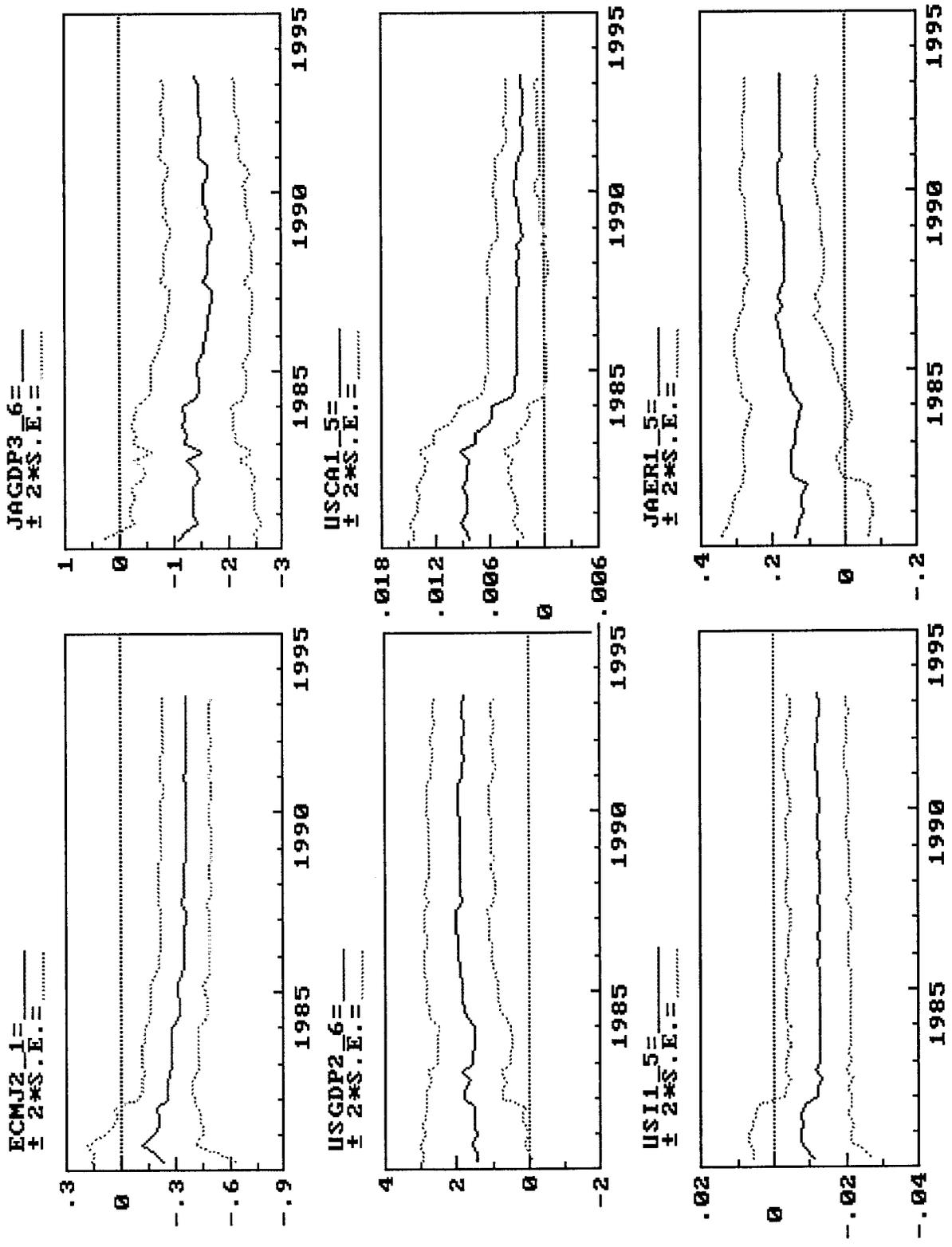


Figure 10. Recursive Estimation Results for Japanese Yen/U.S. Dollar, Parameter Constancy

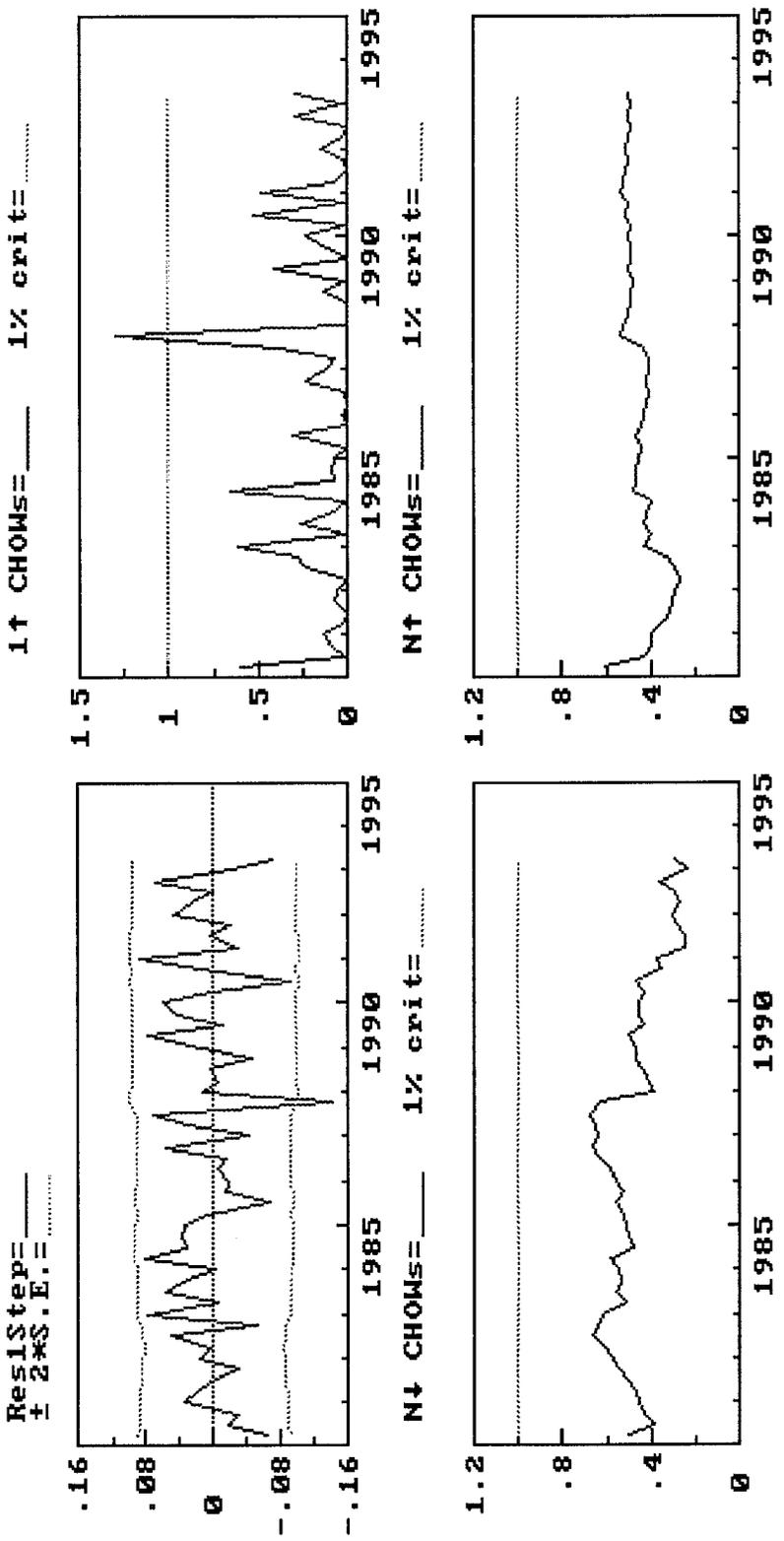


Figure 11. Fitted and Forecast Results for Japanese Yen/U.S. Dollar

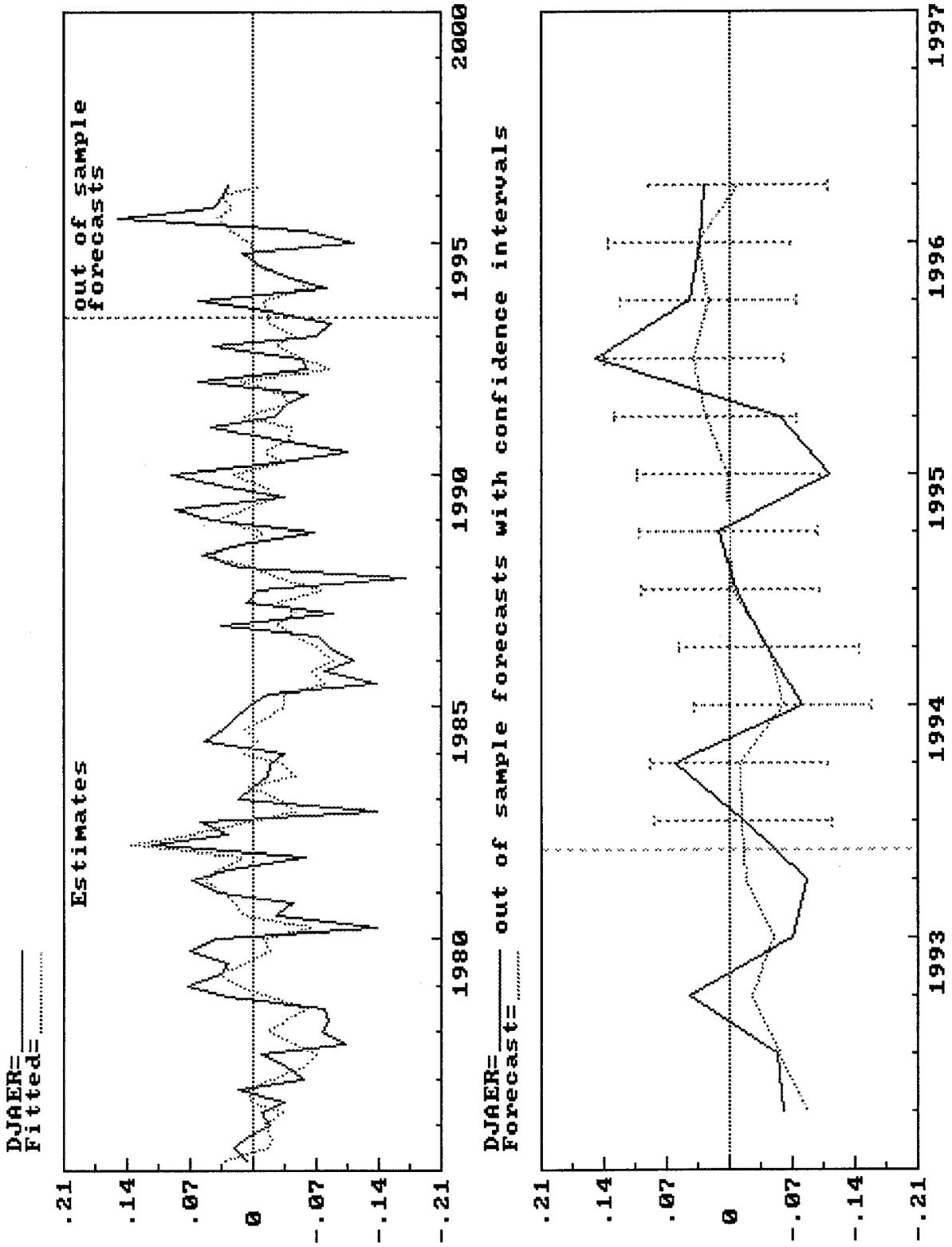


Table 5. Japanese Yen/U.S. Dollar: Encompassing Results Comparing the Model Estimate and Random Walk Model

---

**Forecast encompassing**

Dependent Variable: Forecast error from Model (17)  
 Explanatory variables: forecast from random walk model

The present sample is: 1993 (2) to 1996 (2)

| Variable | Coefficient | Std.Error | t-value | t-prob | PartR <sup>2</sup> |
|----------|-------------|-----------|---------|--------|--------------------|
| Constant | -0.0033     | 0.017     | -0.19   | 0.85   | 0.0031             |

R<sup>2</sup> = 0    $\sigma$  = 0.060   DW = 1.89  
 RSS = 0.044 for 1 variables and 13 observations

The test that the coefficient on the explanatory variable is zero is significant at a 1% level.

**Model Encompassing**

Encompassing test statistics  
 The present sample is: 1975 (2) to 1993 (2)

Model 1 = Model (17)  
 Model 2 = Random walk

$\sigma_1$  = 0.061    $\sigma_2$  = 0.049    $\sigma[\text{Joint}]$  = 0.049

| Test        | Form                 | Model 1 v Model 2 | Form                 | Model 2 v Model 1 |
|-------------|----------------------|-------------------|----------------------|-------------------|
| Cox         | N(0,1)               | 0.3               | N(0,1)               | -34.06            |
| Ericsson IV | N(0,1)               | -0.29             | N(0,1)               | 26.22             |
| Sargan      | Chi <sup>2</sup> (1) | 0.085             | Chi <sup>2</sup> (6) | 29.59             |
| Joint Model | F(1,66)              | 0.084             | F(6,66)              | 7.67              |

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As a result of these findings, it would seem appropriate to approach cautiously the question of identifying “exchange rate misalignments”. Moreover, in view of the limited findings on the role of the current account balances in explaining movements in exchange rates, in the context of high capital mobility and low sovereign risks, it might be appropriate to reexamine the information content of models which link the identification of exchange misalignments to development in such balances.

### DATA SET USED IN THE PAPER

All the data are from IFS, unless otherwise noted.

1. Interest rate (\*\*I) 3-month T-bill rates for Canada, U.K., and U.S. For Japan it is deposit rate. For Germany, it is 3-month FIBOR rate (from ADB).
2. Inflation variables (\*\*PI) are calculated from difference of the log of consumer price indices.
3. \*\*GDP are real GDP in logs.
4. \*\*ID denotes interest differential vis-à-vis U.S. interest rates, they are calculated as  $(1+i/400/1+i^*/400)$ .
5. Exchange rates (\*\*ER) are end of period rates of the price of U.S. dollar in domestic currency, they are in logs.
6. Current account balances (\*\*CA) are in levels, some of them are in U.S. dollars, others in domestic currencies.

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