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# Japanese Effective Exchange Rates and Determinants: Prices, Real Interest Rates, and Actual and Optimal Current Accounts[1]

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**Abstract**

This paper empirically analyzes Japanese long-run exchange rates from several perspectives. Several exchange rate models are considered, including the purchasing power parity, the real interest differential model, and the hybrid models *à la* Hooper and Morton (1982). A notable feature of the latter models is that the current accounts are introduced as determinants of the exchange rates; one type of hybrid model uses the actual current account, and the other the optimal current account, which is calculated using the present value model suggested by Campbell and Shiller (1988). The paper finds that the long-run specification is sensitive to the specification of the model.

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Contents

**Summary**

This paper empirically analyzes Japanese effective exchange rate movements in the long run and, in particular, addresses the potential problems in estimating them. This exercise was conducted using several exchange rate models: the purchasing power parity (PPP), the interest differential model (RID), and two types of hybrid models. The hybrid models incorporate the current account balances in PPP; the first model considers the actual current accounts and the second the optimal current accounts. The optimal current accounts are calculated using the present-value approach developed by Campbell and Shiller (1988).

We find, first, that the long-run estimates appear to be sensitive to the underlying economic theory, even though statistically insignificant variables are removed from our long-run specification. We also find that the short-run specification may be affected by that of the long-run. In our study, the RID requires fewer variables in tracing the short-run dynamics of the Japanese yen because of the introduction of real interest rates in the long-run specification.

## I. INTRODUCTION

This paper analyzes the behavior of the Japanese effective exchange rates during the recent floating rate period by estimating the long-run rates from several exchange rate models. Therefore, the degree and the duration of the misalignment of the exchange rates can be observed by comparing the actual exchange rates with our estimated long-run rates. Furthermore, this paper examines questions related to the potential problems in estimating long-run exchange rate levels; in particular, it discusses the sensitivity of long-run rates to underlying economic theories and problems posed by the definition of the variables.[2]

The importance of understanding long-run equilibrium rates has been pointed out with reference to many countries. The debate over the Japanese yen has intensified since the early 1980s when the existence of US twin deficits (fiscal and trade deficits) became one of the major focuses of US macroeconomic policy. The long-run exchange rates have also been analyzed in the context of (adjustable) fixed exchange rate regimes. The level at which the UK sterling entered into the European Exchange Rate Mechanism is often argued as one reason for its subsequent departure in 1992 (Wren-Lewis *et al* 1991). The existence of a large and persistent misalignment may force a country to face speculative attacks from investors, for instance, as in Mexico in 1994. The high potential costs of such attacks has forced researchers and policy-makers to analyze carefully the question of whether actual exchange rates are at appropriate levels.

Several exchange rate models are used in this paper to identify long-run exchange rate levels. In addition to the purchasing power parity model (PPP), the paper uses the real interest differential model (RID) originally developed by Frankel (1979). The common feature of these monetary models is that the long-run exchange rates can be determined by the relative prices. This paper also tests an hybrid model, which incorporates the current account balance into our standard benchmark model. Hooper and Morton (1982) is an example of a study that extends the conventional monetary model by incorporating the current account. The hybrid model is introduced, in part, to resolve the inability of the monetary models to capture real shocks or a time-varying risk premium. This approach is found to be supported by a number of empirical studies. Mussa (1986) and Huizinga (1987) produce evidence of significant fluctuation in the real exchange rates for major industrialized countries, and Lee and Enders (1991) and Clarida and Gali (1994) decompose nominal exchange rate movements into temporary and permanent components using the Blanchard and Quah (1989) method. The latter shows that about 65 percent of the variance in the dollar-yen real exchange rate is attributable to real shocks, which can be interpreted as being permanent. Furthermore, Baldwin and Krugman (1989) argue that even temporary shocks may have a permanent effect on real exchange rates.

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[2] Bayoumi *et al* (1994) and Driver and Wren-Lewis (1998) consider the sensitivity of the long-run level to the assumptions imposed on the trade equation. Bayoumi *et al* (1994) show that the highest estimated rates may differ by between approximately 10 to 30 percent from the lowest estimated values.

Similarly, evidence of the existence of a time-varying risk premium has been reported (MacDonald and Torrance, 1988).

This paper consists of five sections. Section 2 summarizes the specifications of the exchange rate models used in this study. Section 3 discusses the data used, as well as the methodology to estimate the optimal current account. Section 4 presents some empirical results in both the long- and short-run contexts. Although our main focus is on long-run rates, the paper also considers how different estimates of these rates affect the short-run specification of the model given that recent econometric modeling techniques suggest that the long-run disequilibrium levels, or the error correction mechanism (ECM), should be introduced into the short-run analysis. Section 5 provides a summary of the main conclusion of the paper.

## II. THEORETICAL MODELS

This section describes the three exchange rate models, PPP, the hybrid, and the simplified RID models. A common feature of these models is that long-run exchange rates are determined by economic fundamentals, such as prices. In this respect, their power to explain the volatility of exchange rate movements is limited. However, since the volatility, which may be caused by news and/or the expectations of investors, is assumed to have only transitory effects on exchange rates, these three models may be good candidates for long-run exchange rate analysis.

### A. Purchasing Power Parity

This model is one of the long-standing concepts in international financial research[3] and has been the subject of intensive empirical examination over recent decades.[4] This model is often discussed in the context of two countries, and the absolute version of PPP can be expressed, in logarithm form, in terms of the price differential:

$$\bar{s}_t=\bar{p}_t-\bar{p}^*_t+u_t \qquad [1]$$

where the nominal exchange rate at time $t$ is expressed by $s_t$, prices by $p_t$. A variable with a bar indicates its long-run value and an asterisk, the foreign variable. In our study, therefore, an increase in the exchange rates implies depreciation of the currency. The residual, $u_t$ is, in this case, equals the long-run real exchange rate $q_t$ ($u_t=\bar{q}_t$) since [1] maintains the homogeneity restriction on prices. Furthermore, in order for the long-run PPP to be valid, it must be

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[3] Dornbusch (1988) and Isard (1995), for instance, summarize its history, which can be traced back to the 16th or the early 17th century.

[4] See Froot and Rogoff (1995), Rogoff (1996) and MacDonald (1995) for a review of the empirical results of PPP; Bleaney and Mizen (1995) review the empirical analysis of real exchange rates; Officer (1976) reviews the theory and the potential problems of PPP.

stationary.[5] This treatment of PPP is consistent with Cassel (Officer 1976), and states that the domestic price increase produces an equi-proportional increase in the exchange rate in the long-run *ceteris paribus*. At the same time, researchers have already pointed out several problems associated with PPP and the conditions required for its validity include non-existence of trade barriers, transportation costs and exchange rate controls, and that all goods are tradable, and no product differentiation exists.[6]

Recent studies show some empirical evidence favorable to the long-run PPP. A time-series technique, the cointegration method originally developed by Engle and Granger (1987), may be one of the most appropriate techniques for examining the validity of the long-run PPP hypothesis since it allows for short-run deviation of the exchange rates from the long-run level. The cointegration method does not examine model [1] directly in the sense that this test does not impose homogeneity restrictions on prices *a priori*.[7] Nevertheless, the relaxation of parameter restrictions may be a more appropriate test since the homogeneity restriction on prices may not be reasonable for several reasons including price measurement error and/or existence of transportation costs (Taylor, 1988).[8] Early studies using the Engle-Granger method failed to find such a long-run relationship (Taylor, 1988; Mark, 1990). However, once a more powerful test, the multivariate cointegration (Johansen, 1988) is employed, such a relationship can be empirically supported (Cheung and Lai, 1993; MacDonald, 1993). This paper also focuses on the long-run PPP, which imposes no homogeneity restrictions on prices.

### B. Hybrid Model

Although PPP is the most frequently used long-run exchange rate model, there are several others that have been developed based on PPP. Indeed, this type of modification has been conducted in a variety of ways,[9] but this paper focuses on the current accounts.

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[5] In contrast, Roll (1979) and Rogoff (1992) develop a theoretical reasoning for the unit root process for the real exchange rates.

[6] The possibility that the productivity differentials between tradable and non-tradable sectors will cause the violation of the constant real exchange rates was pointed out by Balassa (1964) and Samuelson (1964). Other conditions include that the price weights are identical for the same product in the two countries.

[7] In this respect, the cointegration test applied to the relationship between exchange rates and relative prices differs from the unit root test to the real exchange rates in equation [1].

[8] Whether the parameter restriction can be accepted by the data can be statistically tested in the Johansen test framework, and indeed, the majority of previous research suggests that the homogeneity restriction cannot be supported by the data (MacDonald, 1995).

[9] Clarida and Gali (1994) discuss sources of real exchange rate movements. Hsieh (1982), for

(continued...)

The link between current accounts and exchange rates has been discussed for a long time, and one simple form is the model which predicts exchange rate movements by the relative prices and the current accounts:

$$\bar{s}_t = \bar{p}_t - \bar{p}_t{*} + \Lambda CA_t \qquad [2]$$

where *CA* stands for the current account balance. The specification of this model is essentially identical to that used in Fisher *et al* (1990) and Sarantis (1995) when the real interest parity condition holds in their models. The possibility of the existence of the long-run real interest rates will be considered later. Furthermore, equation [2] can be transformed to a real exchange rate equation such that the long-run real exchange rates are a function of the current (trade) accounts, and this specification is studied by Rahman *et al* (1997). The parameter sign of current accounts (Λ) can be either positive or negative, and interpretation of the introduction of the current account balance differs among researchers. On one hand, the study of Fisher *et al* (1990) and Sarantis (1995), the current account is expressed in terms of the GDP which is interpreted as the time-varying risk premium, and they argue that the exchange rates are negatively correlated to the current account. Other researchers (Leventakis, 1987; Meese and Rogoff, 1983a, 1983b) use the cumulative current accounts instead of current accounts, and Meese and Rogoff, for instance, interpret the cumulative current accounts as a determinant of the real exchange rates,[10] and indicate that the exchange rate is a negative function of the current account. On the other hand, the Marshall-Lerner condition predicts a positive relationship between current accounts and exchange rates. The co-existence of the current account surplus and the appreciation of the yen, which was the typical characteristic of Japan prior to the recession in the 1990s, seems to suggest a negative relationship between the exchange rate and current account. Equation [2] imposes homogeneity restrictions on prices; however, these restrictions will be relaxed in our estimation.[11]

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[9](...continued)
instance, look into the importance of wages and productivity, Dornbusch (1980) and Frankel (1982) incorporate real financial wealth; some other factors often believed to be important include oil prices (McGuirk 1983), fiscal stance and investment location (Ahmed, 1986; Dooley and Isard, 1991; Koray and Chan, 1991), and terms of trade (Ostry, 1988). Lippert and Breuer (1994) introduce corporate and personal taxes as well as variables to reflect changes in consumer preference into PPP.

[10] Isard (1995).

[11] Haynes and Stone (1981) argue against the imposition of *a priori* parameter restrictions since they could be the source of wrongly signed parameters. Furthermore, they argue that this problem is more pronounced when subtractive linear constraints, rather than additive constraints, are imposed since when two variables are positively correlated, the signs may be reversed.

Another type of hybrid model was developed using the basic idea of Hooper and Morton (1982). Although one of their contributions is often considered to be the introduction of the actual current account into the exchange rate equation, the more fundamental contribution may be that the long-run or optimal current account is considered: in their paper, the long-run real exchange rate is defined as a function of the long-run (optimal) current account and other related factors. Here we utilize the optimal current account, which can be obtained under the joint null hypothesis of perfect capital mobility and forward-looking rational behavior *à la* Hall (1978) of a representative economic agent (see the survey of Obstfeld and Rogoff, 1995). This approach has been used by several researchers (Sheffrin and Woo, 1990; Otto, 1992; Ghosh, 1995; Ghosh and Ostry, 1995) in order to test the hypothesis of international capital mobility, and this test requires calculation of the optimal current account. Here this optimal current account will be used as one of the determinants of the exchange rates.

The values of the optimal current accounts (*OPTCA*) can be obtained by using the maximizing utility behavior of an agent, which in turn is a function of the consumption. The latter must also be consistent with the random walk consumption model. The intertemporal maximization problem can be written as:

$$\sum_{t=0}^{\infty} \delta^t E[u(C_t)]$$

where $0 < \delta < 1$ and $\delta$ is the subjective discount rate ($\delta = 1/(1+r)$) and the real interest rate ($r$) is assumed to be constant. Furthermore, the utility function is assumed to be the quadratic utility function: $u(C_t)=C_t-aC_t^2/2$. Therefore, $u'(C_t)=1-aC_t$ and $u''(C_t)=-a$, and for $u(C_t)$ to be concave, the parameter, $a$, must be positive.[12] The representative agent will maximize its utility subject to the budget constraint: $F_{t+1} = GDP_t - INV_t - GOV_t + (1+r)F_t$. The term, $F_t$, is the net factor income abroad, $INV_t$ is investment and $GOV_t$ government current expenditure. The optimal private consumption level that is consistent with this budget constraint and utility function, can be obtained by solving this static budget constraint forwardly and imposing a transversality condition. Then, the optimal private consumption level (*OPTC*) at time $t$ can be written as:

$$OPTC_t=rF_t+r\delta\sum_{i=0}^{\infty} \delta^i E_t Z_{t+i}$$

where $Z_t = GDP_t - INV_t - GOV_t$. This is the forward-looking consumption function and asserts that the current consumption depends on the expected future income level. Thus, the anticipated temporary increase in income will raise the current consumption in order to smooth the consumption level. Contrarily, a reduction in expected income will result in lower

[12] Under the assumption of constant interest rates, the first order condition of the utility function and the expected form of the Euler equation ($u'(C_t)=\delta(1+r_{t+i})u'(E_tC_{t+i})$) will bring about the random walk consumption function as in Hall (1978).

consumption at time $t$. Then finally, the following optimal current account balance can be derived using equation: $OPTCA_t = GDP_t + rF_t - INV_t - GOV_t - OPTC_t$.[13]

$$OPTCA_t = -\sum_{i=1}^{\infty} \delta^i E_t \Delta Z_{t+i}$$

This equation states that the current account is an optimal forecast of a weighted sum of a future value of a change in income, $\Delta Z$, and an expected increase in future income ($\Delta Z$) will result in a current account deterioration in time $t$ in order to smooth the consumption path. Similarly, an expected temporary fall in investment results in a one-for-one decrease in the optimal current account. Therefore, the forward-looking agent will utilize the current account to smooth out the consumption level in response to future shocks. This is the fundamental argument of this model. This optimal account is used to predict the long-run real exchange rates in our study, and therefore, Hooper and Morton's insight for the long-run real exchange rate equation can be written, using *OPTCA*, as:

$$\overline{q_t} = \xi OPTCA_t + \gamma f(x)_t$$

where $\xi$ and $\gamma$ are coefficients and $x$ is the vector of other factors, which in our study is ignored. This is the real exchange rate equation, but it can be covered to the nominal exchange rate equation using equation [1] (replacing $u_t$ with $\overline{q_t}$),

$$\overline{s_t} = \overline{p_t} - \overline{p_t}* + \xi OPTCA_t \qquad [3]$$

Therefore one interpretation of this model is that it relaxes the assumption of constant real exchange rates over time. As in model [2], the parameter of the current account balance, $\xi$, is uncertain. In our study, the optimal current account balance is exogenously calculated, and the method of calculation will be discussed in the next section.

### C. Real Interest Differential (RID) Model

One variant of PPP is the real interest differential model which was originally developed by Frankel (1979), and has become one of the most popular exchange rate models in the early 1980s. In contrast to previous models, the RID is viewed as a disequilibrium model in theory, since domestic interest rates are allowed to differ from foreign ones even in the long-run. However, consideration of the RID in the long-run context may be more plausible, in particular, when the data is analyzed in the finite sample context: it will most likely fail to

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[13] See Otto (1992). Sachs (1982) argues for current accounts being divided into consumption-tilting and consumption-smoothing components. Our equation is applicable only when the consumption-smoothing component is considered in the current account. In other words, here we explicitly assume that there is no consumption-tilting component.

establish evidence for the existence of the long-run real interest parity condition. Indeed, the latest empirical studies show somewhat supportive evidence for this treatment of the RID. MacDonald and Nagayasu (1998) find the existence of statistically significant cointegrations in this specification, and furthermore show statistically that some real interest rates remain relevant in the cointegrating relationship using the Japanese bilateral exchange rate. The results obtained by MacDonald (1998) are stronger. He studies the real exchange rate behavior relative to the real interest rates, which is essentially equivalent to our model [4], and using the Johansen method, he reports existence of a long-run relationship.[14]

As in PPP, this model asserts that the long-run exchange rates will be determined by the price differentials. However a novel feature of this model is that the real interest rate differential will explain the dynamics of the nominal exchange rate movements, and unlike the uncovered interest parity (UIP), RID asserts that it is the real rates which are expected to be more relevant factors. In our analysis, a simplified version of the original model is used. This model is developed without any equilibrium conditions in the money market, and therefore, our RID model has no explicit money specification. This may represent an advantage, at least on empirical grounds, since most previous studies on money demand have found an instable relationship between key variables in the money demand function (Boughton 1991).

As a result, the simplified RID model consists of two fundamental assumptions. The first is the long-run PPP, which is equation [1]. The second, following Frankel (1979), is related to the dynamics of the exchange rates.

$$s_t - \bar{s}_t = -1/\theta[(i_t - \pi_t) - (i*_t - \pi*_t)]$$

where $0 < \theta < 1$, i represents nominal interest rates and $\pi$ expected inflation rates. According to the Fisher parity condition, $(i_t - \pi_t)$ can be approximated by real interest rates ($r$). The parameter, $\theta$, implies the speed of adjustment to the long-run path, and $\theta$ approaching infinity suggests the high speed of adjustment. Thus, this equation simply asserts that a transitory discrepancy between the current and long-run rates can be explained by the real interest differentials between two countries. When the real interest parity condition holds, the actual rates are expected to be the same as the long-run path. A combination of equation [1] with the expected long-run real exchange rates being zero and the above dynamic equation will yield the following relationship.

$$s_t = \bar{p}_t - \bar{p}*_t - 1/\theta(r_t - r*_t) \qquad [4]$$

This model is called here the simplified RID.

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[14] However, there are other studies which show a very weak relationship in the long-run context between real exchange rates and interest rates. They include Baxter (1994), Edison and Pauls (1993), Edison and Melick (1995) and Meese and Rogoff (1988).

## III. Data Description

In our analysis, we use data from *International Financial Statistics*, covering the period 1974Q3-1996Q4 unless otherwise indicated. The exchange rates are effective rates,[15] which are more appropriate than bilateral ones since some of our models include the current accounts, which include the third country effect. Our study uses the consumer price index, and foreign variables in our models such as $p^*$ and $r^*$ are obtained using the trade weights against remaining G-7 countries,[16] and then one aggregated foreign price and foreign interest rate are produced. Our weights are calculated annually and suggest that the majority (about 70 percent on average) of Japanese trade was conducted with the US.[17] The expected inflation rates are obtained using the moving average method. Most of our nominal rates are market rates with 3 month maturity (*line 60b* for France, Germany, Italy, Japan and UK, and *line 60c* for Canada and US). The real interest rates are calculated by applying the Fisher parity condition to these expected inflation and nominal interest rates. The other variable, current account (*CA*) is obtained by deducting private consumption (*C*), government current expenditure (GOV), and changes in inventories and gross fixed capital formation (*INV*) from the gross national product (*GNP*).

The optimal current account can be obtained using the method developed by Campbell and Shiller (1987), and we shall closely follow their approach. The first stage of their method is to construct the vector autoregression (VAR). In the finite sample case, the appropriate lag, j, can be determined approximately using the VAR.

$$\begin{bmatrix} \Delta Z_t \\ CA_t \end{bmatrix} = \begin{bmatrix} a(L) & b(L) \\ c(L) & e(L) \end{bmatrix} \begin{bmatrix} \Delta Z_{t-1} \\ CA_{t-1} \end{bmatrix} + \begin{bmatrix} \epsilon_t \\ \eta_t \end{bmatrix}$$

where the polynomial operators, $a(L)$, ..., $e(L)$ are all order j. The choice of the lag length must ensure that the residuals are white noise. The jth order VAR can also be written as:

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[15] A definition of the effective exchange rate is explained in *World Economic Outlook*, an IMF publication.

[16] Our weight for country 1 is calculated as: $Weight_{1t}=(X_{1t}+M_{1t})/\sum_{i=1t}^{6}(X_{it}+M_{it})$, where $X_{it}$ denotes exports and $M_{it}$ imports for country 1 at time $t$.

[17] IMF, *Direction of Trade Statistics* is used to calculate the trade weights.

$$\begin{bmatrix} \Delta Z_t \\ \vdots \\ \Delta Z_{t-j+1} \\ CA_t \\ \vdots \\ CA_{t-j+1} \end{bmatrix} = \begin{bmatrix} a_1 & \cdots & \cdots & a_j & b_1 & \cdots & \cdots & b_j \\ 1 & 0 & \cdots & \cdots & \cdots & \cdots & \cdots & 0 \\ \vdots & \ddots & & & & & & \\ 0 & 0 & 1 & 0 & & & & \\ c_1 & \cdots & \cdots & c_j & e_1 & \cdots & \cdots & e_j \\ 0 & \cdots & \cdots & 0 & 1 & & & \\ \vdots & \vdots & \vdots & \vdots & 0 & \ddots & & \\ 0 & \cdots & \cdots & \cdots & \cdots & \cdots & 1 & 0 \end{bmatrix} \begin{bmatrix} \Delta Z_{t-1} \\ \vdots \\ \Delta Z_{t-j} \\ CA_{t-1} \\ \vdots \\ CA_{t-j} \end{bmatrix} + \begin{bmatrix} \epsilon_t \\ 0 \\ \vdots \\ 0 \\ \eta_t \\ 0 \\ \vdots \\ 0 \end{bmatrix}$$

or in a more compact form as: $K_t = AK_{t-1}+v_t$, where $K = [\Delta Z,\ CA]'$ and $v = [\epsilon,\ \eta]'$. One weak implication from the present-value model is that $CA$ must linearly Granger-cause $\Delta Z$ which is consistent with a forward-looking behavior, and this can be tested by imposing some parameter restrictions on this VAR. If $H_t$ is the limited information set available at time $t$ and consists of current and lagged $K$, then the expected future value of $K$ (at time $t+i$) conditional upon the restricted information set $H$ is:

$$E(K_{t+i}|H_t)=A^iK_t$$

If we define g as a (2j×1) column vector with unity in the j+1st element and zero elsewhere, $h$ as a similar vector with unity in the first element and zero elsewhere, then we can derive the following equation using the law of iteration:

$$g'=\sum_{i=1}^{\infty}\delta^i h'A^i=h'\delta A(I-\delta A)^{-1}$$

These are the restrictions implied by the present value model. Then, the optimal forecast of the current account (*OPTCA*) can be obtained using the above expressions.

$$-OPTCA_t=\sum_{i=1}^{\infty}\delta^i E[\Delta Z_{t+i}|H_t]=h'\delta A(I-\delta A)^{-1}K_t$$

Therefore, if the present-value model is correct, the predicted optimal value of the current account must be equal to a consumption-smoothing current account. Although it is of less concern to our analysis, a more formal test has been suggested by Campbell and Shiller, who propose an analysis of the variance of these two variables in order to test perfect capital mobility: the variance ratio (i.e., Var(*CA*)/Var(*OPTCA*)) must be unity when the capital markets are perfectly integrated with the rest of the world.

Our estimates of *OPTCA* are based on the VAR, using the sample period 1960Q1-1996Q4, with 4 lag lengths, which ensure the white noise residual. The real interest rates in our study are 3 percent per annum[18] and the results are presented in Figure 1. The actual current account soared to its record level in the mid-1980s followed by a reduction, owing mainly to the appreciation of the yen, and again its level increased in the early 1990s. These graphs show the high correlation between these two current accounts: the correlation coefficient is found to be 0.853. Furthermore, the level of actual Japanese current account surplus is well beyond the optimal level, a phenomenon that became apparent in the early 1980s and has persisted since then.

However, as mentioned by previous studies (Sheffrin and Woo, 1990; Otto, 1992; Ghosh, 1995), empirical support for the present value model is very weak. One implication of the theoretical model is that the current account should Granger-cause $\Delta Z$. This proposition is not accepted by our data since the null hypothesis of non-causality cannot be rejected ($\text{Chi}^2$ (4) = 4.055).[19] Another implication can be examined by calculating the variance ratio (Var(*CA*)/Var(*OPTCA*)); a ratio greater than unity implies that the actual current account is more volatile than the optimal one. The high ratio of our estimates, 2.793, suggests that an economic agent utilizes the current account to smooth the consumption path more than the optimal level. Obstfeld and Rogoff (1995) explain this excess volatility using the same reason for excess consumption volatility known as the Deaton paradox.[20] The formal test of whether these two current accounts are identical is statistically implemented. If they are statistically the same, the homogeneity restriction should be accepted in current accounts. Our results show that this proposition is strongly rejected ($\text{Chi}^2$ (1) = 100.54). Therefore, although the implication for the present-value model is statistically very weak, the fact that the actual and optimal current accounts differ implies that the introduction of both into exchange rate equations may well be worthwhile.

The time-series properties of each variable are examined using the standard Augmented Dicky-Fuller (ADF) test.[21] This has become standard practice since Granger and Newbold (1974) warned of the possible spurious results when the non-stationary time-series are analyzed. The

[18] Although constant interest rates are sometimes argued as one reason for the poor performance of the present value model (Mankiw 1981), our results (which are not reported here) do not show strong sensitivity in the optimal current accounts to changes in real interest rates.

[19] This empirical result is consistent with Ghosh (1995).

[20] Deaton (1992) reviews a general argument for excess volatility of consumption. The fact that our optimal current account is a function of income growth rather than income level, may be one explanation for our findings.

[21] Campbell and Perron (1991) discuss the statistical power of unit root tests in discriminating the null and alternative hypotheses, and the ADF is one of the most reliable tests of this type.

results are summarized in Table 1. Following previous studies (Fisher *et al,* 1990; Sarantis, 1995), the two types of current accounts, *CA* and *OPTCA*, are expressed in terms of *GDP*. The long data sample (1960Q1-1996Q4) is used to calculate the optimal current accounts because previous researchers have found that Japanese current accounts appear to be non-stationary only when the data of the recent floating rate period is considered. The test (level) examines the null hypothesis of the unit root against the alternative of stationarity, and another test (difference) analyses the null of the time-series being integrated of order one, I(1) against the alternative of I(2). We consider two cases in which the trend and/or constant terms are included in our testable specification. Based on critical values obtained from the method developed by MacKinnon (1991), our results show that the null for the first test (level) cannot be rejected but the second test (difference) can be rejected for most cases except for the current account balance (*CA*) and $\Delta Z$. This implies that our variables are I(1) except these two variables. The last two variables seem to be stationary, which is required for our calculation of the optimal current account, since the first test rejects the null hypothesis for these cases.

## IV. EMPIRICAL ANALYSIS

Long-run analysis forms a large portion of economic analysis, and indeed most economic theory attempts to explain equilibrium conditions, while the dynamic adjustment to the long-run path is often discussed as an additional factor or is simply ignored. This phenomenon seems to have some consistency with the recent evolution of the econometric modeling approach of the general-to-specific method. Here, a long-run analysis is implemented using cointegration methods. Furthermore, since long-run analysis has a significant implication and is incorporated in the short-run analysis of the general-to-specific approach, although this paper concerns mainly the long-run and develops the theoretical models in this context, short-run dynamics will also be discussed.

### A. Long-run Analysis

In this section, long-run analysis is conducted in a number of different ways in line with the development of time series techniques. The two methods employed here were developed by Johansen (1988) and Pesaran *et al* (1996). One notable difference between these techniques is that while the former investigates the long-run relationship in the context of a system of equations, the second is based on a single reduced form equation.

Johansen developed the multivariate cointegration approach based on the maximum likelihood method, and his technique has several advantages over predecessors such as the Engle-Granger test (1987). One notable feature of the Johansen method is that it can explicitly deal with the potential existence of more than one cointegrating vector in the system. Since the specification of a testable model is often derived from several economic behavioral assumptions, multiple long-run relationships are often found in economic analysis. Another interesting feature is that since the Johansen method is based on the VAR, the issue of endogeneity of variables can be legitimately ignored when testing long-run relationships. In addition, the dynamic nature of the test specification leads to the fact that the long-run estimates are expected to be less affected by small sample distortion (Banerjee *et al*, 1986). Finally, in the presence of significant cointegrating vectors, these estimates can be proved to converge to the true values at a faster speed than otherwise and are thus called superconsistent (Stock 1987). The existence of statistically significant cointegrating vectors implies that there are some linear combinations of variables which are stationary as a group and suggests the validity of the specification in the long-run context. Since a greater number of long-run relationships in the system implies stronger stability in the system, the degree of stability in the long-run specification can also be examined by analyzing the number of such long-run relationships.

The Pesaran *et al* test (1996) utilizes the autoregressive distributed lag (ADL) model for determining evidence of a long-run relationship. The application of ADL to long-run analysis is not new, and indeed Hendry and von Ungern-Sternberg (1981) have used ADL in order to obtain a long-run relationship in their consumption analysis. One advantage of using ADL is that a long-run relationship, which directly corresponds to the variable of interest, can be obtained.[22] The fact that the Johansen procedure explicitly addresses the issue of potential multiple cointegrating vectors is discussed as one advantage. However, this is an advantage in modeling only when these significant cointegrating vectors are uniquely identified.[23] It often happens that cointegrating vectors cannot be uniquely identified using economic theory. However, the test developed by Pesaran *et al* has several other advantages over alternatives. One of its most notable features is that the existence of the long-run relationship is tested without any *a priori* knowledge of the order of integration of the time-series (i.e, I(0) or I(1)) or of the possibility of cointegration. Since the power of existing unit root tests to identify the order of integration, in particular, whether I(0) or I(1), is always questionable, their test may be useful.[24] Another helpful feature of this test is that it does not matter whether the explanatory variables (e.g., interest rates and current accounts) are exogenous or not (Pesaran and Shin 1997) since the long- and short-run parameters with appropriate asymptotic inferences can be obtained by applying OLS to ADL with an appropriate lag length. A general specification of this test can be expressed as:

$$\Delta s_t=\alpha_0+\alpha_1 t+\gamma s_{t-1}+\varsigma x_{t-1}+\sum_{i=1}^{p}\xi_i\Delta s_{t-i}+\sum_{i=0}^{k}\phi_i\Delta x_{t-i}+\epsilon_t$$

[22] This is also true for the Engle-Granger method although their testable specification is *ad hoc*.

[23] One way to identify the unique cointegrating vectors in the multiple cointegration setup is to impose theoretical values on them. However, it often happens that economic theory does not provide researchers with exactly the same number of long-run relationships or even if it does, the parameter restrictions that are consistent with economic theory may not be accepted by the data.

[24] See Campbell and Perron (1991) for a summary of comparisons of the power of the unit root tests.

where $x$ is a vector of explanatory variables and the parameters can be obtained by OLS. Testing the existence of a long-run relationship can be conducted by examining the joint null hypothesis that $\gamma = \varsigma = 0$ against the alterative of $\gamma \neq 0$, and therefore this test resembles testing the existence of ECM after estimating the short-run dynamic specification. Existence of a long-run relationship can be confirmed once this null is successfully rejected. Since a conventional distribution cannot be applied in this context, Pesaran *et al* provide critical values based on their stochastic simulation. The fact that their test considers two extreme cases: I(0) and I(1), leads to calculation of the two extreme critical values, which create the critical value band. Therefore, the null hypothesis can be rejected when statistical values are greater than the upper boundary and cannot be rejected when they are less than the lower ceiling. When the statistics are within the band, the result is inconclusive.

Table 2 summarizes our results from the Johansen and Pesaran *et al* tests, and equations [1]-[4] in this table correspond to models developed in the previous section. For the Johansen test, the existence of numbers of statistically significant cointegrations can be tested using the two standard statistics, the maximum likelihood ($\lambda$-max) and trace (Trace) statistics, both of which are suggested by Johansen and Juselius (1992). Our results from the Johansen method confirm that all our specifications are valid in the long-run context. The null hypothesis of non-cointegration can be rejected by both maximum likelihood and trace statistics for all models. Furthermore, these statistics suggest that even our simplest model, PPP, has two long-run relationships and the number of significant long-run relationships increases once the real interest rates and/or current accounts are introduced in our benchmark model. Although these two statistics at times provide evidence for a different number of significant cointegrating vectors, it seems that there are three long-run relationships in equations [2], [3] and [4]. Therefore, we conclude that all these models contain valid long-run specifications, and our empirical evidence suggests that real interest rates and current accounts are relevant determinants of the long-run exchange rates. Therefore, all of our models can be used for our subsequent long-run analysis.

Existence of a long-run relationship is also tested using the method developed by Pesaran *et al.* The bottom of Table 2 contains our F statistics for all models as well as critical bands for the 10, 5, and 1 percent significance. In general, this test provides somewhat weaker evidence of the existence of a long-run relationship than the Johansen test. Our F statistics suggest that the null hypothesis can be rejected for models [2] and [4] at the 5 and 1 percent level respectively, since their F values are greater than the corresponding upper levels of critical values. This provides evidence of the existence of a long-run relationship in these models. For other models, their F statistic lies somewhere within the band using the 5 or 10 percent significance level, implying that for these models, the test of existence of a long-run relationship is inconclusive. The fact that all F statistics are greater than the lower band suggests that none of these cases seems to offer evidence of a non-long-run relationship, which is consistent with the Johansen test.

Empirical findings from our unit root and two types of cointegration tests seem to suggest the existence of long-run relationships in all of our specifications. Therefore, we can proceed to further long-run analysis. Here the ADL method, which can be thought of as an extension of the Pesaran *et al* test, is used since, as mentioned, it can avoid the problem of identifying unique cointegrating vectors. A recent development of the ADL has been achieved by Pesaran and Shin (1997). They argue that obtaining the long-run estimates using the ADL has several advantages, in particular, in comparison with the fully modified OLS approach developed by Philips and Hansen (1990), and their Monte Carlo simulation shows some evidence of superiority of using ADL for long-run estimates in the finite sample context. Consider a simple ADL model,

$$s_t=\alpha_0+\alpha_1 t+\sum_{i=1}^{p}\phi_i s_{t-i}+\sum_{i=0}^{k}\beta_i x_{t-i}+\epsilon_t$$

where $x$ contains determinants of exchange rates, and $\epsilon_t$, is white noise and stationary and $t$ = 1, ..., T. The terms, $\alpha_0$, $\alpha_1$, $\phi_i$, and $\beta_i$ are parameters and their long-run estimates can be obtained as:

$$\overline{\alpha_0}=\alpha_0/(1-\phi_1-\phi_2...\phi_p),\ \overline{\alpha_1}=\alpha_1/(1-\phi_1-\phi_2...\phi_p),\ \text{and}\ \overline{\beta}=(\beta_0+\beta_1...\beta_k)/(1-\phi_1-\phi_2...\phi_p)$$

where the variables with a bar denote the long-run parameters. Here OLS is applied for estimation, and these estimates are obtained by first running ADL, which has at most 3 lags for all variables, and then the best specification of the ADL is chosen based on the Schwarz Bayesian criterion (SBC). The domestic prices have been found to be insignificant in all of our long-run specifications and so is the domestic real interest rate in equation [4]. Therefore, these variables are removed from our original specification. Table 3 summarizes these estimates of all models with several descriptive statistics to understand the performance of the ADL. Our residual diagnostic tests include the autocorrelation (AR) and normality tests, and are based on the Lagrange multiplier method and the Doornik and Hansen (1994) method respectively. All our ADL specifications seem to capture well the data generating process by judging the results from diagnostic tests. Furthermore, the validity of these specifications in the long-run context is re-checked, this time using the standard ADF test. This test is applied to the residual, $\epsilon_t$, in the above long-run relationship. All models successfully reject the null of the unit root test in favor of stationarity, and therefore, these specifications seem appropriate in the long-run.

Furthermore, from this table, we can make several further observations. All foreign prices have a positive sign at the 1 percent significance, and the foreign real interest rates in equation [4] enter significantly negatively as economic theory would suggest. Similarly, the actual and optimal current accounts enter negatively equations [2] and [3] respectively, suggesting the co-existence of currency appreciation and current account improvement during our sample period. Although some estimates are statistically insignificant, they are obtained from the parameters of the ADL, which are jointly tested and proved to be significant at the 1 percent level (see F test).

The long-run exchange rates which are obtained using ADL estimates are plotted along with the actual exchange rates in Figure 2. In general, the Japanese exchange rate seems to have moved closely alongside our estimated long-run rates over the recently floating rate period. Furthermore, all our estimates seem to predict the same level of exchange rates around 1991. However, the level of our long-run estimates in the first half of the 1980s seems to differ depending on the model used. This is a time when the spread between the real interest rate in Japan and in its major trading partners widened, and furthermore, the actual and optimal current accounts had started to grow at different speeds. The relatively higher foreign real interest rates seem to explain the upward movement of the long-run rates in the early 1980s obtained in equation [4]. Furthermore, over the period between 1983-1988, equation [2], which contains the actual current account, suggests a further appreciation of the yen compared with equation [3] with the optimal current account. However, apart from that period, it is not very clear if the model with actual current accounts consistently indicates a long-run exchange rate lower than that predicted by equation [3]. Generally, compared with the long-run estimate of Song (1997) based on the natural real exchange rate (NATREX) model originally developed by Stein (1994), our estimates seem to be less highly correlated with the actual rates.[25] This may be partly due to the fact that our model still relies on the partial equilibrium approach and this shows the sensitivity of the estimates to the underlying economic theory.

### B. Short-run Analysis

The fact that there is at least one cointegration in our specifications leads us to introduce the ECM in the short-run analysis. These short-run models are constructed following the spirit of a general-to-specific approach, and thus our initial models are specified with four lags of all variables, which ensures that the residuals are white noise. Our conditions of whiteness are examined using a residual diagnostic test, which has been used in the previous section. The general short-run model can be expressed as:

$$\Delta s_t = a(L)\Delta s_{t-1} + b(L)\Delta x_t + \alpha(s_{t-1} - \beta x_{t-1}) + \epsilon_t$$

where $L$ is a lag operator, the vector, x, contains explanatory variables and the residual, $\epsilon$, is white noise. The variables that have been found to be irrelevant in the long-run, the domestic price and interest rate, are also introduced in our short-run analysis in order to capture the dynamics of the exchange rates. The term, $(s_{t-1} - \beta x_{t-1})$, is the ECM and the cointegrating parameters, $\beta$, have already been discussed; as shown in Table 3, all ECMs are stationary. Our final models are completed after a reduction of this general model by removing the statistically insignificant variables. This process continues as long as the residuals are white noise.

Table 4 summarizes the results. The results suggest that our final models seem to capture appropriately the information in the data. All models contain one lagged exchange rate, which is always positively correlated with the current rates. This may be consistent with the view of chartists who predict the future rate based on the past movements of rates. ECMs in all equations are negative, implying that the model is converging to the long-run path, and they are

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[25] Song (1997) uses Japanese bilateral exchange rates.

statistically significant at the 1 percent level. The domestic and foreign inflations enter in equations [2] and [3] and they turn out to be statistically significant at the 10 percent level in equation [3] but are insignificant in equation [2]. They are left in the model in order to ensure that the models pass our diagnostic tests. Although the original RID model states that the real interest rate differentials will explain the exchange rate dynamics, there are none left in our study. This may present some indirect evidence that real interest rates are relevant only in the long-run. Similarly, the non-existence of the (differenced) current accounts in the dynamic model is not surprising as they are expected to be relevant only in the long-run.

Furthermore, it is interesting to discover that equation [2], which provides the theoretical explanation of the exchange rate fluctuation, requires the least number of explanatory variables, while other models require more variables in order to ensure white noise residuals. This may be attributable to the fact that the introduction of real interest rates in the long-run specification yields a higher level of volatility or fluctuation in the long-run exchange rates (see Figure 2), and these models require fewer variables to explain the short-run dynamics. This offers evidence that the long-run specification considerably affects the final short-run specification: it seems that the richer the long-run specification, the fewer variables are required to explain the short-run movements in the reduced form equation analysis. This is intuitively easy to understand and is consistent with our results.

## V. CONCLUSION

This paper empirically analyzes nominal exchange rate movements in the long-run context using Japanese data, and in particular, this paper addresses the potential problems in estimating long-run rates. This experiment was conducted by estimating long-run exchange rates from several reduced form models, and then comparing them with actual rates.

Our results provide several conclusions. Generally, the Japanese yen seems to have moved closely to the fundamentals during 1974-1996. Our results also show that the long-run estimates can be very sensitive to the specification of the exchange rate model, which in turn is based on corresponding economic theory. In 1983-1988, we have observed a large discrepancy in long-run rates that are predicted from models with different types of current accounts. During this period, the model with actual current account implies a further reduction (appreciation) of the yen than the model with the optimal current account, which is consistent with the fact that actual current account shows a higher surplus than the optimal one. However, this trend is less obvious in the 1970s and the 1990s. Similarly, when the real interest differential is introduced into our basic model, the estimated long-run rates are found to be quite different from the actual levels and predictions from other models. Although this did not seem to last for long and indeed vanished in a year or so, the model with the real interest rates may have lead to a high level of long-run rates in the early 1980s when real interest differentials became obvious.

This long-run analysis is extended to our short-run study. Our results show that RID which in theory has a mechanism to explain short-term diversion, requires the least number of explanatory variables in our dynamic models while the other models require more (lagged) variables to trace the actual exchange rate movements. This suggests the importance of considering the long-run specification even in the short-run analysis because the variables relevant in the short-run could, to some extent, be influenced by the long-run specification.

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Table 1. Unit Root Tests

| | Level | | Difference | |
|---|---|---|---|---|
| | Constant | Constant + Trend | Constant | Constant + Trend |
| s [a] | -1.354 | -3.180 | -6.337 * | -5.826 * |
| p [a] | -2.406 | -2.785 | -4.295 * | -5.314 * |
| p* [a] | -1.840 | -1.441 | -2.097 | -3.933 * |
| r [a] | -2.647 | -3.628 * | -5.506 * | -5.267 * |
| r* [a] | -1.723 | -1.998 | -7.081 * | -6.724 * |
| CA [b] | -2.259 | -3.554 * | --- | --- |
| $\Delta$Z [b] | -5.643 * | -5.651 * | --- | --- |
| CA/GDP [c] | -2.041 | -2.087 | -4.353 * | -4.780 * |
| OPTCA/GDP [c] | -2.201 | -3.648 * | -6.365 * | -7.286 * |

Note: All critical values are obtained using the method developed by MacKinnon (1991), and the statistics with the 5 percent significance level are marked with one asterisk. $\Delta Z$ = GDP-GOV-INV. The data sample covers the period 1975Q1-1996Q4 for [a], 1960Q1-1996Q4 for [b] and 1973Q3-1976Q4 for [c].

Table 2. Test of Existence of Long-run Relationships

| | Johansen Test | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | λ-max | | | | Trace | | | |
| H0: r | [1] | [2] | [3] | [4] | [1] | [2] | [3] | [4] |
| 0 | 27.26 ** | 42.55 ** | 41.88 ** | 38.79 * | 60.06 ** | 95.90 ** | 92.97 ** | 103.5 ** |
| 1 | 24.19 ** | 27.14 ** | 25.51 ** | 29.80 * | 32.80 * | 53.35 ** | 51.09 ** | 64.76 ** |
| 2 | 8.604 | 17.19 * | 16.74 ** | 17.05 | 8.604 | 26.21 ** | 25.58 * | 34.96 ** |
| 3 | | 9.022 | 8.844 | 11.74 | | 9.022 | 8.844 | 17.91 |
| 4 | | | | 6.167 | | | | 6.167 |

| | Test by Pesaran *et al* | | | |
|---|---|---|---|---|
| | [1] | [2] | [3] | [4] |
| F | 3.583 | 4.461 * | 3.824 | 5.292 ** |
| 10% | 3.182-4.126 | 2.711-3.800 | 2.711-3.800 | 2.425-3.574 |
| 5% | 3.793-4.855 | 3.219-4.378 | 3.219-4.378 | 2.850-4.049 |
| 1% | 5.288-6.309 | 4.385-5.615 | 4.385-5.615 | 3.817-5.122 |

Note: Critical values simulated by Osterward-Lenum (1992) are employed in this analysis. The statistics which are significant at the 5 and 1 percent level are marked with * and ** respectively. In addition, the figures in [ ] and ( ) are standard errors and degrees of freedom respectively.

Table 3. Long-run Estimates

| | [1] | [2] | [3] | [4] |
|---|---|---|---|---|
| Constant | -0.423 | -1.599 | -0.800 | -1.046 |
| | [0.629] | [0.921] | [0.669] | [0.387] |
| p* | -0.942 | -0.626 | -0.841 | -0.873 |
| | [0.145] | [0.228] | [0.160] | [0.081] |
| r* | --- | --- | --- | 0.046 |
| | | | | [0.012] |
| CA/GDP | --- | -0.115 | --- | --- |
| | | [0.064] | | |
| OPTCA/GDP | --- | --- | -0.063 | --- |
| | | | [0.057] | |
| F test | F(3, 88) | F(4, 87) | F(4, 87) | F(5, 86) |
| | =2368.4 ** | =1876.8 ** | =1766.4 ** | =1401.4 ** |
| SBC | 156.489 | 157.249 | 154.848 | 160.022 |
| Unit root test [a] | -2.528 * | -1.993 * | -2.186 * | -2.516 * |
| Diagnostic test | | | | |
| AR | F(4, 84) | F(4, 83) | F(4, 83) | F(4, 83) |
| | = 0.874 | =0.893 | =0.855 | =1.372 |
| Normality | $Chi^2$ (2) | $Chi^2$ (2) | $Chi^2$ (2) | $Chi^2$ (2) |
| | = 0.883 | =1.245 | =0.535 | =3.746 |

Notes: See Table 2. The F test examines the joint null hypothesis of all parameters being equal to zero in the ADL specification, and SBC stands for the Schwarz Bayesian information criterion. The unit root test is conducted using the ADL without the time trend terms. The results of the autocorrelation (AR) and normality are presented under the diagnostic test.

[a] The unit root test does not contain any deterministic terms.

Table 4. Short-run Exchange Rate Equations

| | [1] | [2] | [3] | [4] |
|---|---|---|---|---|
| Δs(-1) | 0.383<br>[0.093] | 0.307<br>[0.094] | 0.410<br>[0.093] | 0.341<br>[0.088] |
| Δs(-3) | 0.138<br>[0.094] | | | |
| Δp(-4) | --- | --- | -0.752<br>[0.389] | --- |
| Δp*(-2) | --- | -0.965<br>[0.728] | --- | --- |
| Δp*(-4) | --- | 0.983<br>[0.730] | 0.848<br>[0.458] | --- |
| ecm i (-i) | -0.094<br>[0.029] | -0.096<br>[0.023] | -0.125<br>[0.033] | -0.164<br>[0.034] |
| Diagnostic test | | | | |
| AR | F(5, 82)<br>=0.638 | F(5, 81)<br>=1.559 | F(5, 81)<br>=1.063 | F(5, 83)<br>=1.076 |
| Normality | $Chi^2$ (2)<br>=1.879 | $Chi^2$ (2)<br>=3.034 | $Chi^2$ (2)<br>=1.803 | $Chi^2$ (2)<br>=3.945 |

Notes: See previous tables. The negative figures in ( ) indicate the number of lags. The 'ecm i' term represents the error correction mechanism for model i (i = 1 to 4), where I corresponds to model [1] to [4].

Figure 1. The Actual and Optimal Current Accounts

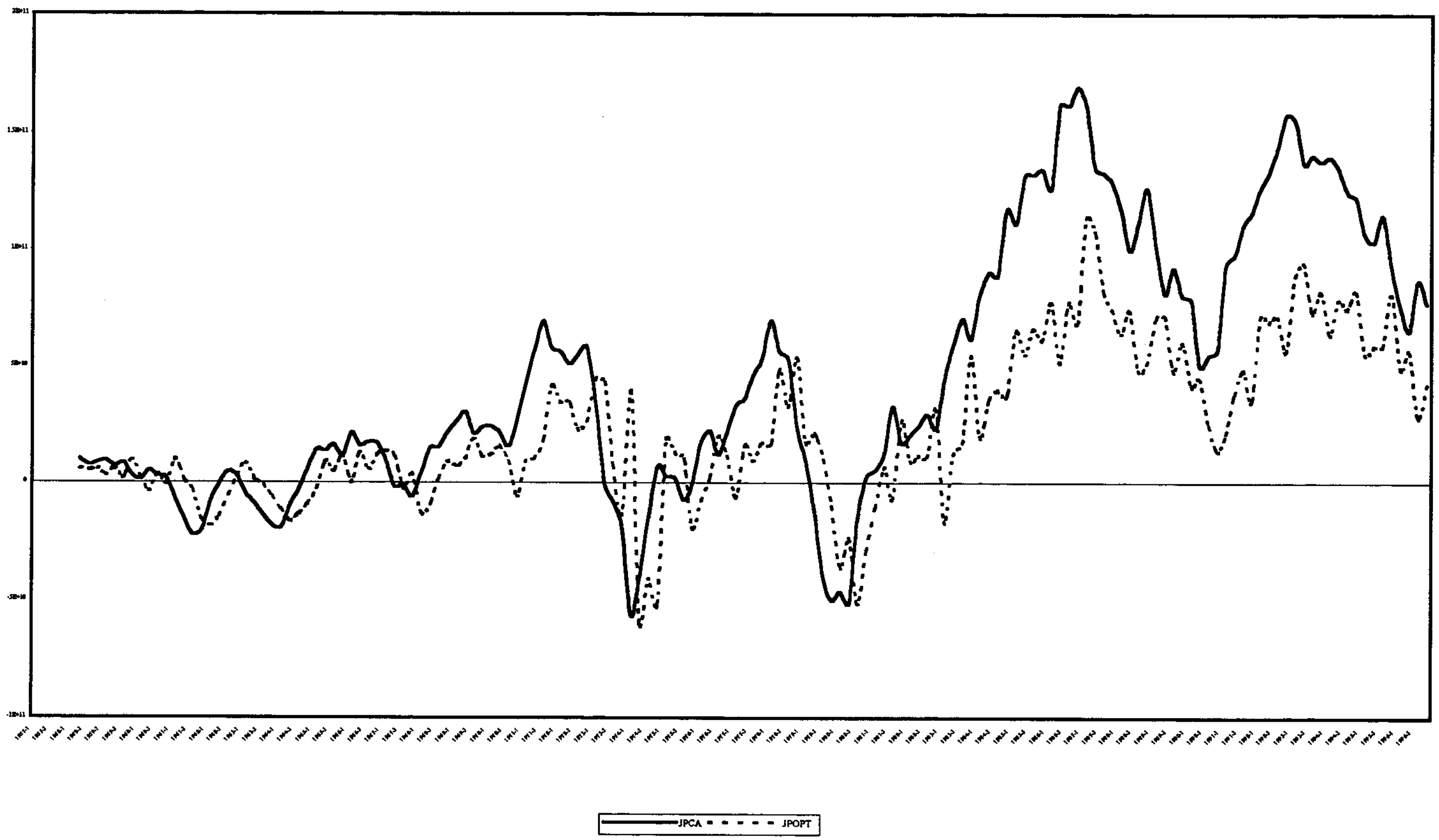

Figure 2. The Actual and Estimated Long-run Japanese Effective Exchange Rates