LONG RUN BEHAVIOUR OF THE REAL YEN/DOLLAR

EXCHANGE RATE

By

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ABSTRACT

Long Run Behaviour of the Real Yen/dollar Exchange Rate

According to Purchasing Power Parity theory, nominal exchange rate changes should equal inflation differentials between countries. In other words, the real exchange rate should be stationary. However, our empirical results show that the real Yen/$ exchange rate is not stationary in the long run. What drives the real Yen/$ exchange rate to deviate from PPP? In this paper, cointegration tests are used to examine the dynamic equilibrium relationship between the real exchange rate and productivity measures, government consumption expenditure, and the terms of trade. The VEC model yields a significant coefficient estimate for each variable included.

Dedicate to my parents.

ACKNOWLEDGEMENTS

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I. Introduction

The real exchange rate is a key relative price in international finance. Thus it is not surprising that there have been numerous studies on the determinants of this variable for various countries.

This paper investigates the determinants of the real Yen/$ exchange rate in the long run. Beginning with purchasing power parity theory, I first test whether PPP holds for the Yen/$ exchange rate, and then try to explain deviations from PPP using three models.

In previous studies of the Yen/$ exchange rate, Lothian (1990) finds evidence that the real exchange rate is trend-stationary for the period 1875-1986. Ito (1997) performs ADF and DF tests on the Consumer Price Index (CPI) and Wholesale Price Index (WPI) based real exchange rate from 1879 to 1995. The WPI-based real exchange rate is trend stationary. The CPI-based real exchange rate tends to depreciate in the pre-WWII period and strongly appreciate in the post-WWII period. Ito concludes the whole sample is non-stationary rather than testing the real exchange rates separately in pre-WWII and post-WWII periods.

Possible explanations for the observed deviations from PPP are provided by Chinn and Johnston (1996). They break these analyses into three groups. The first group adopts the Balassa-Samuelson hypothesis straightforwardly, so that the appreciation of domestic currency is attributed exclusively to supply side factors, such as productivity. The second group introduces some type of rigidity, such as adjustment costs to reallocating factors of

production between sectors, so that demand factors also determine the real exchange rate. The third approach adopts an explicitly intertemporal approach, and may or may not include a specific-factors assumption. In sum, they point out that there is substantial evidence for a productivity-based model of the real exchange rate.

The paper is organized as follows: Section II presents an overview of the data. Section III reports results of unit root tests. An explanation of the observed deviations from PPP is presented in Section IV. The conclusion is in Section V.

II. An overview of the data

If long-run PPP holds, nominal exchange rate changes should equal inflation differentials between countries. Figure 1 plots changes in nominal exchange rates against inflation differentials from 1975 to 1999 using annual data. If PPP holds for the Yen/$ exchange rate, points should be close to the 45° line. Clearly, the Yen/$ series exhibits little regularity and suggests rejection of PPP.

Figure 1. Change in nominal Yen/$ exchange rate (1975—1999) vs. inflation differential
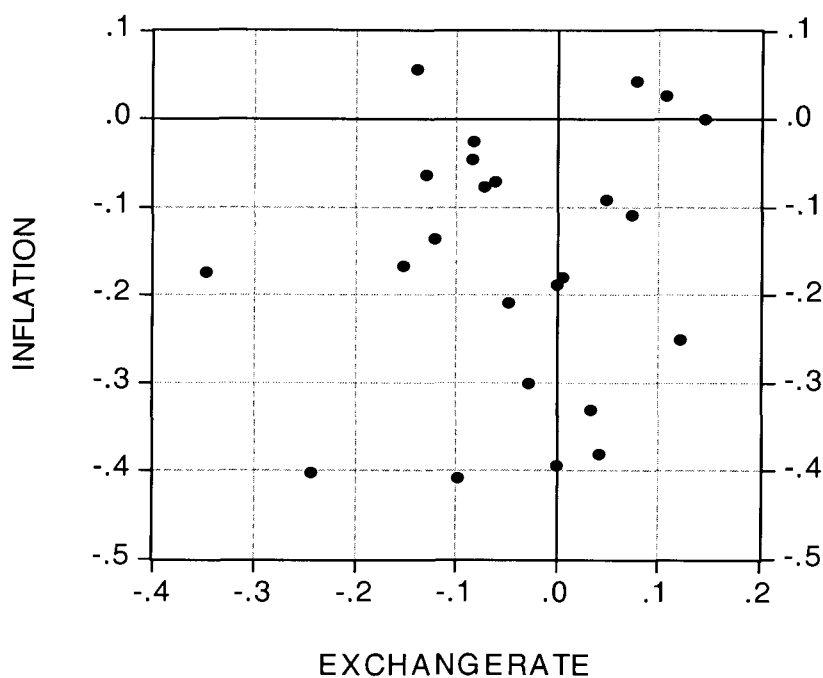
Another implication of PPP is that the real exchange rate should be constant. Figure 2 plots natural logs of annual real exchange rates measured by GDP deflator from 1975 to 1999. It exhibits little stationarity and suggests rejection of PPP.

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Figure 2. Annual real Yen/$ exchange rate (1975—1999)
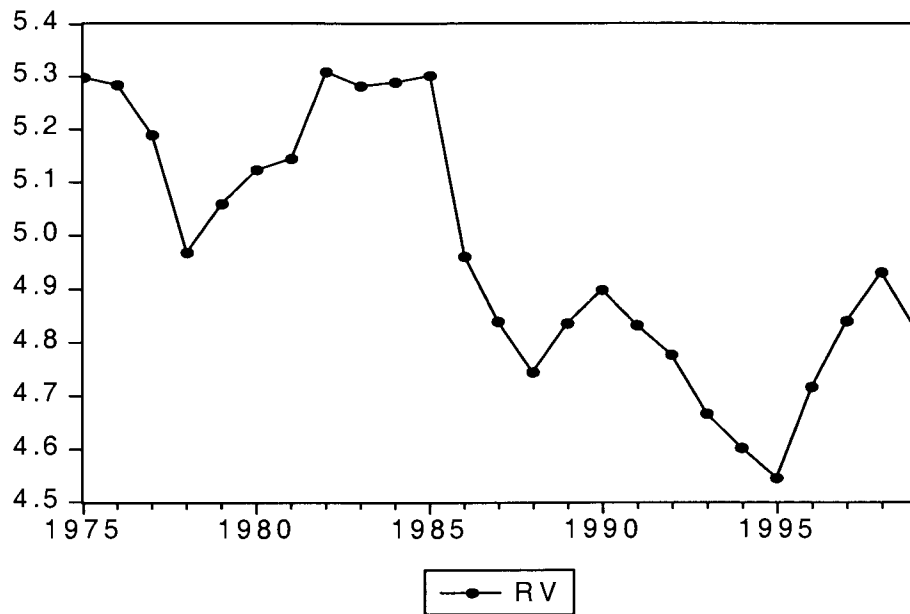
III. Unit root tests

In this section, the ADF test and the KPSS test are applied to our real exchange rates. The Augmented Dickey-Fuller (ADF) test is a standard unit root test with the null of a unit root against the alternative of either level stationarity or trend stationarity. However, classical hypothesis testing tends to accept the null unless there is strong evidence against it and the ADF test has been shown to have low power. Therefore, the KPSS test is also performed, which is based on a null of stationarity.

For the ADF test, the follow equation is estimated:

$$\Delta y_t = \mu + \alpha \, y_{t-1} + \xi t + \sum_{i=1}^{k} c_i \Delta y_{t-i} + \varepsilon_t \tag{1}$$

The first-difference of the log of the real exchange rate is regressed on a constant, a time trend, and its lagged value and K lagged first differences. Although PPP suggests that the real exchange rate should be level stationary, the trend term is included initially to avoid specification bias. It can be dropped from the model if insignificant.

The truncation lag parameter K is chosen by the Schwarz (SIC) criterion. It can also be chosen by a significance test on the last included lag, given a pre-specified maximum. However, the results do not change.

The sample sizes are 25. The pre-specified maximum of K is set to be 5, being approximately the square root of the sample size. Although a trend term seems to be present in the Yen/$ rate, it is not significant at 5%. Nevertheless, ADF tests are

performed with the alternative of both level stationarity and trend stationarity. We fail to reject the null of unit root at even 10%. Test results are shown in table 1.

According to the AR coefficient estimates in ADF tests, we can calculate the half-life of deviations from PPP, which are reported in Table 1 too. The half-life is defined as the number of years that it takes for deviations from PPP to subside permanently below 0.5 in response to a unit shock in the level of series and can be calculated by the following formula:

$$h=\ln(1/2)/\ln\rho \qquad\qquad\qquad (2)$$

where h is the half-life and ρ is the AR coefficient estimates in ADF tests, $\rho=\alpha+1$.

Table 1.

ADF statistics (null: unit root; alternative: level/trend stationary)

Alternative	Lag Length	t-statistics	α	t-statistics for trend	Half-life
Level Stationary[a]	0	-1.54	-0.15		4.265
Trend Stationary[b]	1	-2.76	-0.12	-1.98	5.422

[a]MacKinnon critical values for rejection of hypothesis of a unit root against level stationary: 1% Critical Value –3.74; 5% Critical Value –2.99, 10% Critical Value -2.63

[b]MacKinnon critical values for rejection of hypothesis of a unit root against trend stationary: 1% Critical Value –4.42, 5% Critical Value –3.62, 10% Critical Value -3.24.

Standard unit root tests are not very powerful against relevant alternatives, i.e. they often fail to reject the null of unit root when the time series is actually stationary. The KPSS test, on the other hand, is based on a null of stationarity against the alternative of a unit root and it yields compatible results with the previous ADF test. Based on the test results, we fail to reject the null of trend stationary at even 10% but we reject the null of level stationary at 5%. However, even though we cannot reject the null of trend stationary, it doesn't mean that PPP holds in this case. In fact, the presence of either a unit root, or a deterministic time trend, or both, would indicate rejection of the Purchasing Power Parity hypothesis. Table 2 provides KPSS test results.

Table 2. KPSS statistics (null: trend/level stationary; alternative: unit root)

Null	Sample Size	KPSS Statistic
Trend Stationary[a]	25	0.08
Level Stationary	25	0.55*

[a]Critical values were tabulated in Kwiatkowski et al. (1992). For finite sample, critical values are 0.216 at 1%, 0.146 at 5% and 0.119 at 10%.

[b]Critical values were tabulated in Kwiatkowski et al. (1992). For finite sample, critical values are 0.739 at 1%, 0.463 at 5% and 0.347 at 10%.

* denotes statistical significance at the 5% level

IV. Explaining deviations from PPP

1. Possible Explanations for Purchasing Power Disparity

The previous section fails to conclude in favor of the PPP hypothesis. Therefore, this section explores possible explanations for the observed deviations from PPP.

The Balassa-Samuelson hypothesis is possibly the most prominent explanation, and it focuses on supply shocks (productivity differentials between traded and non-traded sector) to the real exchange rate. It states that the conventionally constructed real exchange rate (measured by a broad price index including both traded-sector and non-traded sector, such as CPI, or GDP deflator) will move reflecting the cross-country differences in the relative speed of productivity increases between the traded-sector and the non-traded sector. Since the differences in productivity increases are expected to be larger in high growth countries, the Balassa-Samuelson prediction should be most visible among rapidly growing countries, such as Japan. (Ito, (1997))

A visual inspection of the real Yen/$ exchange rate and productivity differentials in traded sector between Japan and US is provided in Figure 3. (Annual data from 1975 to 1999) It indicates strong correlation between the real exchange rate and productivity differences.

Figure 3. Log real Yen/$ exchange rate and the log productivity differential (Japan minus US)
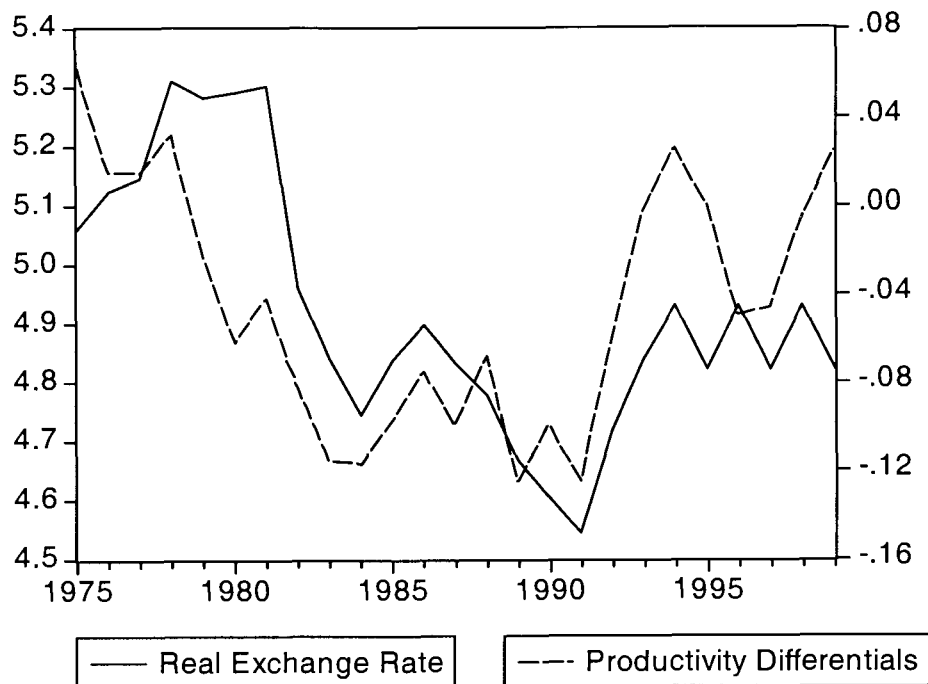
Hsieh (1982) estimates the determinants of the multilateral exchange rates for Germany and Japan over the 1954-1976 period and finds strong evidence supporting the role of productivity differentials. Marston (1987) adopts a similar approach, examining Yen/$ exchange rates over the 1971-1983 period and he finds some evidence in support of this theory. He provides estimates of the effects of relative productivity growth on the real exchange rate in the United States and Japan. Since all variables used by Marston are expressed as logarithmic first difference, he implicitly assumes productivity and the real exchange rate are not cointegrated.

Marston develops expressions for several real exchange rates to show how they are affected by supply factors, which are briefly described below:

The first equation (equation (2)) developed by Marston expresses the aggregate real exchange rate relative to the real exchange rate for traded goods as the difference of two relative prices:

$$R_V - R_{VT} = g^* (P^*_{VN} - P^*_{VT}) - g (P_{VN} - P_{VT}) \tag{3}$$

Where R_V is the real exchange rate measured by the GDP deflator, R_{VT} is the real exchange rate measured by the value added deflator in the traded sector, P^*_{VN} is the value-added deflator in the nontraded sector in US, P^*_{VT} is the value-added deflator in the traded sector in US, P_{VN} is the value-added deflator in the nontraded sector in Japan, P_{VT} is the value-added deflator in the traded sector in Japan. $g^*(g)$ is the share of nontraded goods in total value added in US (Japan).

The equation shows that a rise in nontraded relative to traded prices in Japan leads to a real appreciation of the yen in terms of the GDP deflator as a whole relative to the traded goods deflator. Thus the yen has to appreciate in terms of the aggregate index in order for U.S. – traded goods to remain competitive.

Then Marston develops another equation (equation (3)) to state that the aggregate real exchange rate (that based on the GDP deflator) is influenced by two factors: relative unit labor costs in the traded sectors of the U.S. and Japan (R_{ULCT}) and unit labor costs in one sector of each national economy relative to the other sector.

$$R_V = R_{ULCT} + g^* ((W^*_N - W^*_T) - (H^*_N - H^*_T))$$

$$- g ((W_N - W_T) - (H_N - H_T)) \tag{3}$$

Where H^*_N is the total factor productivity in the nontraded sector in US, H^*_T is the total factor productivity in the traded sector in US, H_N is the total factor productivity in the nontraded sector in Japan, H_T is the total factor productivity in the traded sector in Japan, W^*_N is the nominal wages in the nontraded sector in US, W^*_T is the nominal wages in the traded sector in US, W_N is the nominal wages in the nontraded sector in Japan, W_T is the nominal wages in the traded sector in Japan.

Thus, if there is a faster rate of growth of productivity in the traded sector of Japan, then the real exchange rate of the yen must appreciate relative to R_{ULCT} in order to keep the traded sector of the U.S. competitive.

These studies indicate that there is a statistically significant relationship between labor productivity and the real exchange rate. However, the results differ by specification, by sample and data type. The Johsansen methodology is also used in literature to capture any cointegrating relationship between the real exchange rate and relative productivity variables. Using panel data of 14 countries for 21 years, Strauss (1995) finds eight cases are cointegrated at the 10% significance level. However, Chinn and Johnson (1996) argue that these tests may be sensitive to finite sample size effects.

In the Balassa-Samuelson model, factors are assumed to be perfectly mobile across sectors so that demand shocks, such as government-spending shocks, have no effects on

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relative prices. Instead, real exchange rates depend solely on relative productivity. Countries that experience relatively rapid growth in their tradable goods industries will have appreciating real exchange rates. DeGregorio, Giovannini and Wolf (1994) point out that demand side factors will affect the real exchange rate if the assumption of perfect competition, PPP for traded goods, or perfect capital mobility are relaxed. Rogoff (1992) offers an alternative rationale based on a fixed-factor neoclassical model with traded and non-traded goods. The basic idea is that with open capital markets, agents can only smooth their consumption of tradeables in the face of transitory traded goods productivity shocks. Agents cannot smooth productivity shocks in non-traded goods, but if these are relatively small then traded goods consumption smoothing will lead to smoothing of the intratemporal price of traded and non-traded goods. Since government consumption spending tends to fall heavily on non-traded goods, its effects cannot be smoothed intertemporally. In short, when government spending shifts aggregate demand towards the non-tradable goods sector, the domestic price level increases and the real exchange rate appreciates.

2. Testing procedure and data source

Based on the above discussion, we will use three models to examine the long run relationships. The first model regresses the difference between real exchange rates measured by alternative price indexes on the price differential in the nontraded and traded sectors of each country. The second model regresses the difference between two real

exchange rates on the labor productivity (not total factor productivity since we cannot find reliable data source for that variable) differential in the nontraded and traded sectors of each country. These two models follow the approach of Marston (1987) by log first differencing all variables. The ADF test will also be applied to check for nonstationarity.

The third model includes the terms of trade and relative government consumption spending as additional explanatory variables. We regress the real exchange rate measured by GDP deflators on productivity differentials in the nontraded and traded sectors of each country, the relative terms of trade, and relative government consumption expenditure. Instead of taking first differences of all variables, we apply the Johansen cointegration procedure to find the long run equilibrium relationship among the variables.

First, we perform an ADF test to ascertain the order of integration for each variable. Then the Johansen procedure is applied to test for the existence of any cointegration. Having established a cointegration relationship, we can then use a Vector Error Correction (VEC) model. The VEC model is a restricted VAR with built-in cointegration restrictions. The VEC specification restricts the long-run behavior of the variables to converge to their cointegrating relationship(s) while allowing for short-run dynamics.

There are two tests proposed by Johansen, and described in greater detail in Johansen and Juselius (1990). One is the trace statistic and the other is the maximal eigenvalue statistic. The asymptotic critical values are from Osterwald-Lenum (1992). However, Cheung and Lai (1993) point out that the LR test in the Johansen procedure is based on asymptotic results, and statistical inferences in finite samples may not be appropriate. They formulate

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the finite-sample critical values (CR_{Tj}) as a function of the sample size (T), the number of variables in the estimation system (n) and the lag parameter (k):

$$CR_{Tj} / CR_{\infty} = \beta_0 + \beta_1 SF_j + errors \qquad (4.1)$$

where CR_{∞} is the asymptotic critical value and SF_j is equal to $T/(T - nk)$. Critical values for β_0 and β_1 are tabulated based on response surface analysis. Clearly, the Johansen test is biased towards finding cointegration too often when asymptotic critical values are used. In all the following cointegration tests, finite-sample critical values are reported using the Cheung and Lai correction method.

Data are annual in frequency, for the period 1975-1999. The main rationale for starting the sample in 1975 is to abstract from any transitionary dynamics associated with the breakdown of Bretton Woods. Operational counterparts to the traded and nontraded aggregates in our model follow the approach of Marston (1987). Real exchange rates are measured by GDP deflator and value added deflator in the traded sector. Labor productivity is the real GDP per worker in the traded and nontraded sector in each country. Since the effects of government investment on the real exchange rate are theoretically ambiguous, we focus on government consumption spending, which is obtained as a percentage of GDP. Terms of trade are calculated by dividing export price index by import price index, 1995=100. Above data are mainly derived from OECD's Annual National Accounts and International Financial Statistics (IFS). (Greater detail on the data sources and variable construction can be found in the Data Appendix.)

3. Test results

3.1. Model 1.

All variables are taken as first differences in logs, so they can be interpreted as percentage changes of the corresponding variable from one year to the next. At first ADF tests are performed with the null of unit root and the alternative of both level stationarity and trend stationarity. All these series are stationary and we reject the null of unit root. (See appendix 1 for ADF test results).

Then, we run the OLS model directly. The number in parentheses below the coefficients are t-statistics. (See appendix 2 for test results in details).

Sample Period 1976 -1999:

$$(R_V - R_{VT}) = -0.005 + 0.745 \ (P^*_{VN} - P^*_{VT}) - 0.769(P_{VN} - P_{VT})$$

$$(-1.02) \quad (6.34) \quad\quad\quad (-5.65)$$

Similar to the results by Marston (1987), we have the coefficient for $(P^*_{VN} - P^*_{VT})$ be positive and significant at even 1% level, which means that a rise in nontraded relative to traded prices in the US leads to a rise in R_V relative to R_{VT}; the coefficient for $(P_{VN} - P_{VT})$ be negative and significant at even 1% level, which means that a rise in nontraded relative to traded prices in Japan leads to a fall in R_V relative to R_{VT}. Also, the magnitude of these two coefficients are approximately equal the share of nontraded goods in total value added in each country. The share of nontraded goods in total GDP in US and Japan

in 1995 were 80% and 75.4%, respectively. And the results we get are about 74.5% for US and 77% for Japan.

3.2. Model 2

Again, all variables are taken first differences in the logs and then all these series are stationary by ADF tests. (See appendix 3 for ADF test results). Test results of the OLS model in details are in appendix 4.

Sample Period 1976-1999:

$$R_V = -0.008 + 0.984R_{VT} - 0.331 (H^*_N - H^*_T) + 0.241(H_N - H_T)$$

$$(-1.53) \quad (28.16) \qquad (-1.93) \qquad\qquad (1.93)$$

We get the correct sign for each variable and all variables are significant at 10% level but not significant at 5% except R_{VT}, which is significant at even 1% level. The coefficient of R_{VT} is positive and close to one as Marston suggested.

3.3. Model 3

We use level variables in this model and all variables are I(1) according to ADF test results which are reported in appendix 5. We first test whether variables are cointegrated, then test the VEC model.

Cointegration is tested with the assumption of a linear deterministic trend in data and the cointegration rank test results are presented in appendix 6. If productivity differentials, relative government consumption expenditure and terms of trade fully explain the non-stationary nature of the real exchange rate, then long-run equilibrium conditions probably do not have trends. Under this specification, Trace test indicates 1 cointegrating equation(s) at the 5% level but Max-eigenvalue test indicates that there is no cointegration. If we allow a trend in cointegration, both Max-eigenvalue and Trace test indicate one cointegrating at 5%.

The VEC model yields significant coefficient estimate for each included variable and the test results are reported in appendix 7. The Balassa-Samuelson hypothesis is supported by a positive coefficient on $(H_N - H_T)$ and a negative coefficient on $(H^*_N - H^*_T)$. Coefficients on demand shock variables such as relative government consumption expenditure and the terms of trade are also significant, although with relatively small magnitudes. The trend term is the most significant but its magnitude is relative small.

V. Conclusion

Based on the above discussion, we find that the real Yen/$ exchange rate is not stationary, as predicted by the PPP, and the observed deviations from PPP may be explained by both supply and demand side shocks, including the relative growth performance, public spending, and the terms of trade.

Even though we fail to find support for the PPP by examining real Yen/$ exchange rates, it may be due to the small sample (annual data from 1975 to 1999) we use. Recent studies, exploit more data by using either panel data or longer time series data and higher-powered techniques, and show that long run PPP does hold. For example, Alan M. Taylor (2000) studies data for a group of twenty countries over one hundred years to test long run PPP using multivariate and univariate tests of higher power and finds that long-run PPP can be supported in all cases with allowance for deterministic trends.

Although PPP may indeed hold in the very long run, this is of less concern to our study. What we are really interested in are possible explanations for persistent purchasing power disparity. Our empirical results support the Balassa-Samuelson hypothesis about the effect of relative productivity on the real exchange rates. The coefficients of demand factors are also significant in our models, though with a relatively small magnitude.

However, these results may be attributed to the short-spans of data. By Rogoff (1992), the assumption that all factors are sector-specific is reasonable only in the short- and

possibly medium run. Clearly, support for the intertemporal model is more appropriate when looking at monthly or quarterly movements in the real exchange.

Data Appendix

Except otherwise noted, the data are derived from OECD's Annual National Accounts. In order to find operational counterparts to the traded and nontraded aggregates in our model, we use the division suggested by Marston (1987).

Traded sector:

Manufacturing;

Agriculture, hunting, fishing, and forestry.

Nontraded sector: Construction;

Wholesale and retail trade, restaurants, and hotels;

Finance, insurance, real estate, and business services;

Community, social and personal services

Government services

All energy-intensive subsectors such as mining and quarrying are excluded here. The value added deflators for traded and nontraded goods are weighted average of the subsector deflators, the weights being the relative size of value added in 1995.

Exchange rates

Description: log form of average spot rates, in Yen/$

GDP Deflator: P^*_V/P_V

Description: log form of GDP deflator indexes, 1995=100

Source: IFS

Value Added Deflator in Traded Sector: P^*_{VT} / P_{VT}

Description: Log form of value added deflator in traded sector, 1995=100

Value Added Deflator in Non-Traded Sector: P^*_{VN} / P_{VN}

Description: Log form of value added deflator in non-traded sector, 1995=100

Real Exchange Rates: R_V /R_{VT}

Description: Adjusted by GDP deflator and Value added deflator in traded sector. Logs

form too.

Productivity: H^*_N /H^*_T and H_N / H_T

Description: I get it by taking log form of productivity index (1995=100) in each sector.

At first I get the real GDP for traded / non-traded sector (by using the nominal GDP

divided by the value added deflator I get for traded and non traded sector). Then, dividing

real GDP by the total employment in traded/non traded sector. Finally, I transfer it into

index (1995=100).

Source: OECD's Annual National Accounts and The Bureau of Economic Analysis

Relative Government Consumption Expenditure: $G=G_{US}-G_{JAP}$

Description: Divided government consumption expenditure by gross domestic product

Source: IFS

Relative Terms of trade: T

Description: Terms of trade is calculated by dividing export price index by import price

index, 1995=100. The relative terms of trade T is the difference between the terms of

trade in US and terms of trade in Japan

Source: IFS

Appendix 1. ADF test results for all variables in model 1

> $R_V - R_{VT}$

Null Hypothesis: ($R_V - R_{VT}$) has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic based on SIC, MAXLAG=8)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.084517	0.0426
Test critical values:	1% level	-3.769597	
	5% level	-3.004861	
	10% level	-2.642242	

*MacKinnon (1996) one-sided p-values.

> $P^*_{VN} - P^*_{VT}$

Null Hypothesis: ($P^*_{VN} - P^*_{VT}$) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic based on SIC, MAXLAG=8)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.721344	0.0011
Test critical values:	1% level	-3.752946	
	5% level	-2.998064	
	10% level	-2.638752	

*MacKinnon (1996) one-sided p-values.

> $P_{VN} - P_{VT}$

Null Hypothesis: ($P_{VN} - P_{VT}$) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic based on SIC, MAXLAG=8)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.208996	0.0004
Test critical values:	1% level	-3.752946	
	5% level	-2.998064	
	10% level	-2.638752	

*MacKinnon (1996) one-sided p-values.

Appendix 2. OLS test results for model 1.

Dependent Variable: (R_V - R_{VT})
Sample: 1976 1999

Variable	Coefficient	Std. Error	t-Statistic	Prob.
(P^*_{VN} – P^*_{VT})	0.745041	0.117455	6.343190	0.0000
(P_{VN} – P_{VT})	-0.769307	0.136148	-5.650500	0.0000
C	-0.004541	0.004461	-1.017774	0.3204

R-squared	0.745096
Durbin-Watson stat	1.650514

Appendix 3. ADF test results for all variables in model 2

> H^*_{VN} – H^*_{VT}

Null Hypothesis: (H^*_{VN} – H^*_{VT}) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic based on SIC, MAXLAG=8)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.365359	0.0233
Test critical values:	1% level	-3.752946	
	5% level	-2.998064	
	10% level	-2.638752	

*MacKinnon (1996) one-sided p-values.
and may not be accurate for a sample size of 15

> H_{VN} – H_{VT}

Null Hypothesis: (H_{VN} – H_{VT}) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic based on SIC, MAXLAG=8)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.530264	0.0017
Test critical values:	1% level	-3.752946	
	5% level	-2.998064	
	10% level	-2.638752	

*MacKinnon (1996) one-sided p-values.

➢ R_{VT}

Null Hypothesis: R_{VT} has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic based on SIC, MAXLAG=8)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-3.574101	0.0149
Test critical values: 1% level	-3.752946	
5% level	-2.998064	
10% level	-2.638752	

*MacKinnon (1996) one-sided p-values.

➢ R_V

Null Hypothesis: R_V has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic based on SIC, MAXLAG=8)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-3.566510	0.0151
Test critical values: 1% level	-3.752946	
5% level	-2.998064	
10% level	-2.638752	

*MacKinnon (1996) one-sided p-values.

Appendix 4. OLS test results for Model 2.

Dependent Variable: R_V
Sample(adjusted): 1976 1999
Included observations: 24 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
R_{VT}	0.983717	0.034935	28.15822	0.0000
$(H^*_{VN} - H^*_{VT})$	-0.331231	0.171308	-1.933544	0.0674
$(H_{VN} - H_{VT})$	0.240755	0.124578	1.932564	0.0676
C	-0.008051	0.005261	-1.530134	0.1416
R-squared	0.980616			

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Appendix 5. ADF test results for all variables in model 3

> ➤ G: Relative Government consumption expenditure

Null Hypothesis: G has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic based on SIC, MAXLAG=8)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.071529	0.0049
Test critical values:	1% level	-3.752946	
	5% level	-2.998064	
	10% level	-2.638752	

*MacKinnon (1996) one-sided p-values.

> ➤ T: Relative terms of trade

Null Hypothesis: T has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic based on SIC, MAXLAG=8)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.604192	0.0139
Test critical values:	1% level	-3.752946	
	5% level	-2.998064	
	10% level	-2.638752	

*MacKinnon (1996) one-sided p-values.

Appendix 6. Cointegration Rank Test Results

> ➤ **Assumption: Trend in data but no trend in cointegration**

Series: R_V $(H^*_{VN} - H^*_{VT})$ $(H_{VN} - H_{VT})$ G T
Lags interval (in first differences): 1 to 1

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	5 Percent Critical Value	1 Percent Critical Value
None	0.890525	138.7630	127.3794	139.5965
At most 1	0.808599	87.88551	92.70353	102.9182
At most 2	0.679724	49.85764	63.87235	73.68118

Trace test indicates 1 cointegrating equation(s) at the 5% level

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	5 Percent Critical Value	1 Percent Critical Value
None **	0.890525	50.87746	53.26529	61.01765
At most 1 *	0.808599	38.02786	45.26941	52.45353

Max-eigenvalue test indicates no cointegrating equation(s)

> **Assumption: Trend in data and cointegration**

Series: R_V ($H^*_{VN} - H^*_{VT}$) ($H_{VN} - H_{VT}$) G T
Lags interval (in first differences): 1 to 1

Hypothesized No. of CE(s)	Trace Statistic	5 Percent Critical Value	1 Percent Critical Value
None	223.4971	155.4529	168.7794
At most 1	127.6314	118.1253	130.6671
At most 2	80.14446	85.22176	94.77353

Trace test indicates 2 cointegrating equation(s) at the 5% level
Trace test indicates 1 cointegrating equation(s) at the 1% level

Hypothesized No. of CE(s)	Max-Eigen Statistic	5 Percent Critical Value	1 Percent Critical Value
None	95.86569	59.48882	66.98412
At most 1	47.48694	50.76235	57.31059

Max-eigenvalue test indicates 1 cointegrating equation(s) at the 5% level

Appendix 7. VEC test result

R_V $(H^*_{VN} - H^*_{VT})$ $(H_{VN} - H_{VT})$ G T

Vector Error Correction Estimates
Included observations: 23 after adjusting endpoints
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1
R_V (-1)	1.000000
$(H^*_{VN} - H^*_{VT})$ (-1)	-4.176678
	(1.72162)
	[-2.42602]
$(H_{VN} - H_{VT})$ (-1)	9.203692
	(0.96769)
	[9.51095]
G(-1)	0.340658
	(0.05451)
	[6.24927]
T(-1)	0.090084
	(0.00766)
	[11.7651]
TREND	0.301165
	(0.02790)
	[10.7927]
C	-6.895705

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