LONG RUN BEHAVIOUR OF THE REAL YEN/DOLLAR EXCHANGE RATE

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B.A. Peking University, 2001

PROJECT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTERS OF ARTS

In The Department Of Economics

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SIMON FRASER UNIVERSITY

April 2003

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Title of Project: Long Run Behaviour Of Real Yen/$ Exchange Rates

Author:

Ying Chen
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

I would like to thank my supervising committee Ken Kasa, Brian Krauth and Richard Harris for their valuable insight and support throughout the course of this project. I would also like to thank my colleagues Dan Hao, Masumi Mizoguchi and Ran Shen for their friendship and support.
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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.
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:

\[
\Delta y_t = \mu + \alpha y_{t-1} + \xi t + \sum_{i=1}^{K} c_i \Delta y_{t-i} + \varepsilon_t
\]  

(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:

\[ h = \frac{\ln(1/2)}{\ln \rho} \]  

(2)

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

Table 1.

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

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Lag Length</th>
<th>t-statistics</th>
<th>( \alpha )</th>
<th>t-statistics for trend</th>
<th>Half-life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level Stationary*</td>
<td>0</td>
<td>-1.54</td>
<td>-0.15</td>
<td></td>
<td>4.265</td>
</tr>
<tr>
<td>Trend Stationaryb</td>
<td>1</td>
<td>-2.76</td>
<td>-0.12</td>
<td>-1.98</td>
<td>5.422</td>
</tr>
</tbody>
</table>

*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

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)

<table>
<thead>
<tr>
<th>Null</th>
<th>Sample Size</th>
<th>KPSS Statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trend Stationary(^a)</td>
<td>25</td>
<td>0.08</td>
</tr>
<tr>
<td>Level Stationary</td>
<td>25</td>
<td>0.55(^*)</td>
</tr>
</tbody>
</table>

\(^a\)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.
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:

\[ R_V - R_{VT} = g^* (P^*_V - P^*_T) - g (P_V - P_T) \] (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, \( P^*_V \) is the value-added deflator in the nontraded sector in US, \( P^*_T \) is the value-added deflator in the traded sector in US, \( P_V \) is the value-added deflator in the nontraded sector in Japan, \( P_T \) 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.
\[ R_V = R_{ULCT} + g^* ( (W_N^* - W_T^*) - (H_N^* - H_T^*) ) \]

\[ - g ((W_N - W_T) - (H_N - H_T)) \]

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

\[
CR_{TF}/CR_{\infty} = \beta_0 + \beta_1 SF_{ij} + \text{errors}
\]  

(4.1)

where \(CR_{\infty}\) is the asymptotic critical value and \(SF_{ij}\) is equal to \(T/(T-nk)\). Critical values for \(\beta_0\) and \(\beta_1\) 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).

\[
\begin{align*}
\text{Sample Period 1976 -1999:} \\
(R_V - R_{VT}) & = -0.005 + 0.745 (P^{\ast}_{VN} - P^{\ast}_{VT}) - 0.769 (P_{VN} - P_{VT}) \\
& (-1.02) (6.34) (-5.65)
\end{align*}
\]

Similar to the results by Marston (1987), we have the coefficient for \((P^{\ast}_{VN} - P^{\ast}_{VT})\) 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:

\[ R_v = -0.008 + 0.984 R_{VT} - 0.331 (H_N^* - H_T^*) + 0.241 (H_N - H_T) \]

\[ (-1.53) \quad (28.16) \quad (-1.93) \quad (1.93) \]

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 relatively 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/$

\[ \frac{P_{V}^{*}}{P_{V}} \]

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)

<table>
<thead>
<tr>
<th></th>
<th>t-Statistic</th>
<th>Prob.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Augmented Dickey-Fuller test statistic</td>
<td>-3.084517</td>
<td>0.0426</td>
</tr>
<tr>
<td>Test critical values: 1% level</td>
<td>-3.769597</td>
<td></td>
</tr>
<tr>
<td>5% level</td>
<td>-3.004861</td>
<td></td>
</tr>
<tr>
<td>10% level</td>
<td>-2.642242</td>
<td></td>
</tr>
</tbody>
</table>


- **$P_{VN}^* - P_{VT}^*$**

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

<table>
<thead>
<tr>
<th></th>
<th>t-Statistic</th>
<th>Prob.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Augmented Dickey-Fuller test statistic</td>
<td>-4.721344</td>
<td>0.0011</td>
</tr>
<tr>
<td>Test critical values: 1% level</td>
<td>-3.752946</td>
<td></td>
</tr>
<tr>
<td>5% level</td>
<td>-2.998064</td>
<td></td>
</tr>
<tr>
<td>10% level</td>
<td>-2.638752</td>
<td></td>
</tr>
</tbody>
</table>


- **$P_{VN} - P_{VT}$**

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

<table>
<thead>
<tr>
<th></th>
<th>t-Statistic</th>
<th>Prob.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Augmented Dickey-Fuller test statistic</td>
<td>-5.208996</td>
<td>0.0004</td>
</tr>
<tr>
<td>Test critical values: 1% level</td>
<td>-3.752946</td>
<td></td>
</tr>
<tr>
<td>5% level</td>
<td>-2.998064</td>
<td></td>
</tr>
<tr>
<td>10% level</td>
<td>-2.638752</td>
<td></td>
</tr>
</tbody>
</table>

Appendix 2. OLS test results for model 1.

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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>((P^{<em>}_{VN} - P^{</em>}_{VT}))</td>
<td>0.745041</td>
<td>0.117455</td>
<td>6.343190</td>
<td>0.0000</td>
</tr>
<tr>
<td>((P_{VN} - P_{VT}))</td>
<td>-0.769307</td>
<td>0.136148</td>
<td>-5.650500</td>
<td>0.0000</td>
</tr>
<tr>
<td>(C)</td>
<td>-0.004541</td>
<td>0.004461</td>
<td>-1.017774</td>
<td>0.3204</td>
</tr>
</tbody>
</table>

R-squared 0.745096
Durbin-Watson stat 1.650514

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

\(\Rightarrow H^{*}_{VN} - H^{*}_{VT}\)

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

<table>
<thead>
<tr>
<th>Augmented Dickey-Fuller test statistic</th>
<th>t-Statistic</th>
<th>Prob.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>-3.365359</td>
<td>0.0233</td>
<td></td>
</tr>
</tbody>
</table>

Test critical values:
1% level -3.752946
5% level -2.998064
10% level -2.638752

and may not be accurate for a sample size of 15

\(\Rightarrow H_{VN} - H_{VT}\)

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

<table>
<thead>
<tr>
<th>Augmented Dickey-Fuller test statistic</th>
<th>t-Statistic</th>
<th>Prob.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>-4.530264</td>
<td>0.0017</td>
<td></td>
</tr>
</tbody>
</table>

Test critical values:
1% level -3.752946
5% level -2.998064
10% level -2.638752

RVT

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

<table>
<thead>
<tr>
<th>t-Statistic</th>
<th>Prob.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Augmented Dickey-Fuller test statistic</td>
<td>-3.574101</td>
</tr>
</tbody>
</table>

Test critical values:
- 1% level: -3.752946
- 5% level: -2.998064
- 10% level: -2.638752


RV

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

<table>
<thead>
<tr>
<th>t-Statistic</th>
<th>Prob.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Augmented Dickey-Fuller test statistic</td>
<td>-3.566510</td>
</tr>
</tbody>
</table>

Test critical values:
- 1% level: -3.752946
- 5% level: -2.998064
- 10% level: -2.638752


Appendix 4. OLS test results for Model 2.

Dependent Variable: \( R_{V} \)
Sample(adjusted): 1976 1999
Included observations: 24 after adjusting endpoints

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

24
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)

<table>
<thead>
<tr>
<th>t-Statistic</th>
<th>Prob.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>-4.071529</td>
<td>0.0049</td>
</tr>
</tbody>
</table>

Test critical values:
- 1% level: -3.752946
- 5% level: -2.998064
- 10% level: -2.638752


T: Relative terms of trade

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

<table>
<thead>
<tr>
<th>t-Statistic</th>
<th>Prob.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>-3.604192</td>
<td>0.0139</td>
</tr>
</tbody>
</table>

Test critical values:
- 1% level: -3.752946
- 5% level: -2.998064
- 10% level: -2.638752

Appendix 6. Cointegration Rank Test Results

- Assume: 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

<table>
<thead>
<tr>
<th>Hypothesized</th>
<th>No. of CE(s)</th>
<th>Eigenvalue</th>
<th>Trace Statistic</th>
<th>5 Percent Critical Value</th>
<th>1 Percent Critical Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td></td>
<td>0.890525</td>
<td>138.7630</td>
<td>127.3794</td>
<td>139.5965</td>
</tr>
<tr>
<td>At most 1</td>
<td></td>
<td>0.808599</td>
<td>87.88551</td>
<td>92.70353</td>
<td>102.9182</td>
</tr>
<tr>
<td>At most 2</td>
<td></td>
<td>0.679724</td>
<td>49.85764</td>
<td>63.87235</td>
<td>73.68118</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Hypothesized</th>
<th>No. of CE(s)</th>
<th>Eigenvalue</th>
<th>Max-Eigen Statistic</th>
<th>5 Percent Critical Value</th>
<th>1 Percent Critical Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>None **</td>
<td></td>
<td>0.890525</td>
<td>50.87746</td>
<td>53.26529</td>
<td>61.01765</td>
</tr>
<tr>
<td>At most 1 *</td>
<td></td>
<td>0.808599</td>
<td>38.02786</td>
<td>45.26941</td>
<td>52.45353</td>
</tr>
</tbody>
</table>

Max-eigenvalue test indicates no cointegrating equation(s)
Assumption: Trend in data and cointegration

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

<table>
<thead>
<tr>
<th>Hypothesized No. of CE(s)</th>
<th>Trace Statistic</th>
<th>5 Percent Critical Value</th>
<th>1 Percent Critical Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>223.4971</td>
<td>155.4529</td>
<td>168.7794</td>
</tr>
<tr>
<td>At most 1</td>
<td>127.6314</td>
<td>118.1253</td>
<td>130.6671</td>
</tr>
<tr>
<td>At most 2</td>
<td>80.14446</td>
<td>85.22176</td>
<td>94.77353</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Hypothesized No. of CE(s)</th>
<th>Max-Eigen Statistic</th>
<th>5 Percent Critical Value</th>
<th>1 Percent Critical Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>95.86569</td>
<td>59.48882</td>
<td>66.98412</td>
</tr>
<tr>
<td>At most 1</td>
<td>47.48694</td>
<td>50.76235</td>
<td>57.31059</td>
</tr>
</tbody>
</table>

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

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### 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 [ ]

<table>
<thead>
<tr>
<th>Cointegrating Eq:</th>
<th>CointEq1</th>
</tr>
</thead>
<tbody>
<tr>
<td>( R_V ) (-1)</td>
<td>1.000000</td>
</tr>
<tr>
<td>( (H_{VN}^* - H_{VT}^*) ) (-1)</td>
<td>-4.176678</td>
</tr>
<tr>
<td></td>
<td>(1.72162)</td>
</tr>
<tr>
<td></td>
<td>[-2.42602]</td>
</tr>
<tr>
<td>( (H_{VN} - H_{VT}) ) (-1)</td>
<td>9.203692</td>
</tr>
<tr>
<td></td>
<td>(0.96769)</td>
</tr>
<tr>
<td></td>
<td>[ 9.51095]</td>
</tr>
<tr>
<td>( G ) (-1)</td>
<td>0.340658</td>
</tr>
<tr>
<td></td>
<td>(0.05451)</td>
</tr>
<tr>
<td></td>
<td>[ 6.24927]</td>
</tr>
<tr>
<td>( T ) (-1)</td>
<td>0.090084</td>
</tr>
<tr>
<td></td>
<td>(0.00766)</td>
</tr>
<tr>
<td></td>
<td>[ 11.7651]</td>
</tr>
<tr>
<td>( \text{TREND} )</td>
<td>0.301165</td>
</tr>
<tr>
<td></td>
<td>(0.02790)</td>
</tr>
<tr>
<td></td>
<td>[ 10.7927]</td>
</tr>
<tr>
<td>( C )</td>
<td>-6.895705</td>
</tr>
</tbody>
</table>
Reference


Shen, Ran (2002), “Purchasing Power Parity during the post-Bretton Woods Period: Examination of Two Country Pairs”, *MA Project, Department of Economics, Simon Fraser University*