REAL EXCHANGE RATE BEHAVIOUR: A REPLICATION AND ROBUSTNESS CHECK

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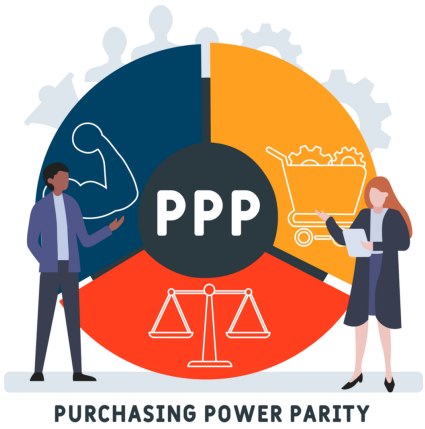


Econometrics 871: Time Series Project

Table of Contents

1 Introduction **3**

2 Context and Evaluation **3**

3 Data **4**

3.1 Wald-Wolfowitz Tests 8

4 Unit Root Tests **8**

5 Variance Ratio Test **10**

6 Conclusion **11**

References **12**

Appendix **13**

1. Introduction

How do we compare living standards and economic productivity between countries? This is one of the questions that macroeconomics attempts to answers and a number of tools have been developed within the field to this end. One of these tools is the Purchasing Power Parity (PPP) theory, which uses a basket of goods to compare the currencies of different countries. This theory has been widely tested using data, and the results have been divisive and somewhat puzzling (El-Gamal & Ryu (2006)).

In this essay, I replicate[1] the paper "Real Exchange Rate Behaviour: Evidence from Black Markets" by Luintel (2000), which tests the PPP hypothesis. Luintel (2000) finds that the behaviour of the real exchange rate is mean-reverting in the long-run, which suggests that the PPP theory is empirically supported. I include some other tests in addition to those presented in the paper as a robustness check on these results.

This essay[2] is organised as follows. Section 2 contextualises Luintel's paper and discusses the robustness checks. Section 3 discusses the data and reports the results of the Wald-Wolfowitz tests. Section 4 deals with the unit root tests and section 5 reports the results of the variance ratio test. The code for this replication can be found on Github here.

2. Context and Evaluation

Luintel (2000) investigates whether the PPP hypothesis holds empirically. To test this theory, Luintel (2000) uses monthly black market real exchange rates (in terms of the US dollar) from eight developing Asian countries: India, Sri Lanka, Myanmar, Malaysia, Pakistan, Philippines, Taiwan and Thailand. Using data from developing countries (rather than from developed countries) was a novel approach for its time. The black market rates are used as a proxy for the float rates of developing countries.

Practically, the paper has two main aims: the first is to determine whether there are segmented trends in the data, and the second is to test whether the panel data is stationary. At the time that this paper was written (early 2000s), the puzzle of PPP was that tests for unit roots failed to reject the null hypothesis. The null hypothesis in these cases was the presence of unit roots; these tests implied non-stationarity and discredited PPP, despite the support from economic theory(El-Gamal & Ryu (2006)).

Luintel (2000) makes use of (more) powerful unit root tests for heterogeneous panels, and finds that real exchange rates are mean-reverting. This was novel for the time as most time-series studies rejected

[1] More accurately, try my best to replicate
[2] This essay was written in R using the package by Katzke (2017)

PPP and concluded that the real exchange rate followed a random walk. This suggested that any shocks to the real exchange rate were persistent and there was no mean-reversion either in the short or long term (Rogoff (1996)). Luintel (2000) finds that the black market real exchange rates do not behave in an excessively volatile manner, which conflicted with the findings of the literature at that time. Additionally, the findings of the study implied that such empirical investigation may not necessarily suffer from survivorship bias.

A critical part of Luintel's paper is testing for unit roots in the panel data, specifically the paper makes use of the Im-Pesaran-Shin (IPS) T-bar test. In addition to replicating this test, I implement several other unit root tests as a robustness check and find that the results are mixed. Luintel (2000: 170) defends the choice of the IPS tests well, citing that they allow for the dynamics and error variances across groups and these tests may have better small sample properties. I run the IPS tests using Luintel (2000)'s specified lags, and the AIC method. I then implement the panel stationarity tests proposed by Levin, Lin & James Chu (2002), Maddala & Wu (1999), Hadri (2002), as well as a bootstrapped panel unit root test from Palm, Smeekes & Urbain (2011) (4).

3. Data

The data used for the analysis is a series on black market nominal exchange rates and consumer price indices (CPI) for 8 developing Asian countries, namely: India, Sri Lanka, Myanmar, Malaysia, Pakistan, Philippines, Taiwan and Thailand. I take a subset of these countries by excluding Taiwan[3] from the analysis. Luintel (2000) sources data from various issues of *Pick's Currency Year Book* and *World Currency Year Book*. The data used for Luintel's paper is accessible through the Journal of Applied Econometrics archive, which is where I attained my data. The sample period runs for 31 periods from January 1958 to June 1989. This sample period is split into two parts: Bretton Woods and after Bretton Woods (also referred to as pre-float period and the float period).

The nominal exchange rates are units currencies per unit of US dollar. There were two mistakes in the nominal exchange rate datasets: for Myanmar November 1974, there was a value of 1.45, which I replaced with 16.5 (based on interpolation). And for the Philippines in September 1975, there was a value of 0.7 with which I replaced with 7.7 (based on interpolation).[4] Luintel sources the CPI figures from various issues of International Financial Statistics (which are included in Luintel's dataset available in the JAE data archives).

To calculate the real exchange rates, I follow the lead of Luintel (2000: 165) and apply the following

[3] I excluded Taiwan because there is some data missing from the set and I don't know how to manage an unbalanced panel. However, it is also interesting to test if the results of the paper hold when taking a subset of the data.

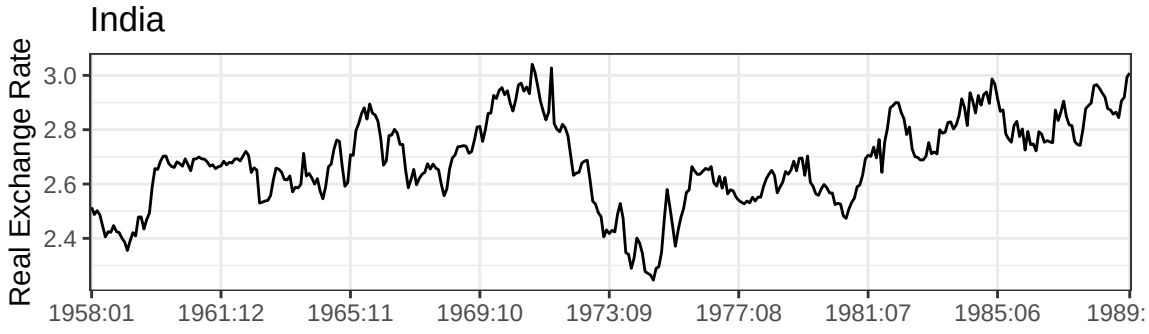
[4] I discovered these mistakes when there was a dramatic difference in my plots of the real exchange rates and Luintel's plots.

formula to the nominal exchange rates:

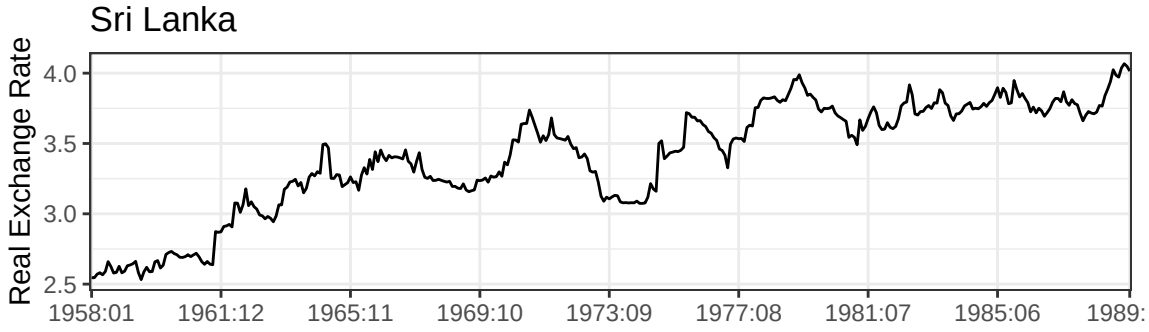
$$rex = log(NominalExchangeRate) - log(CPI) + log(UnitedStatesCPI)$$

I plot the real exchange rate series below in 3.1. The plots below match those of Luintel (2000: 166) and preliminarily indicate that the real exchange rates are trending. Additionally, the graphs show that the black market exchange rates are somewhat volatile. As expected, we see that after the first oil shock of 1973 the currencies appreciated and then slowly reverted. The plots suggest that the trends are segmented. Luintel (2000: 169) tests this hypothesis using formal tests, and I follow suit - the results of the Wald-Wolfowitz Tests are reported below after the plots, in table 3.1.

Real Exchange Rates Plot



Source: Own Calculations



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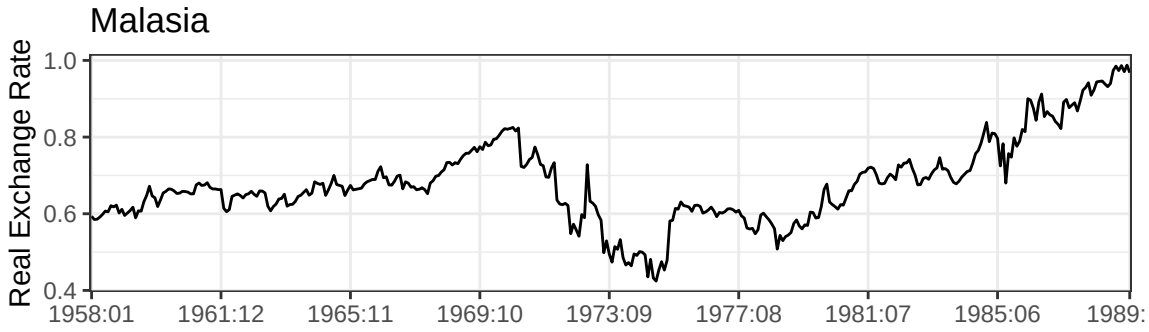

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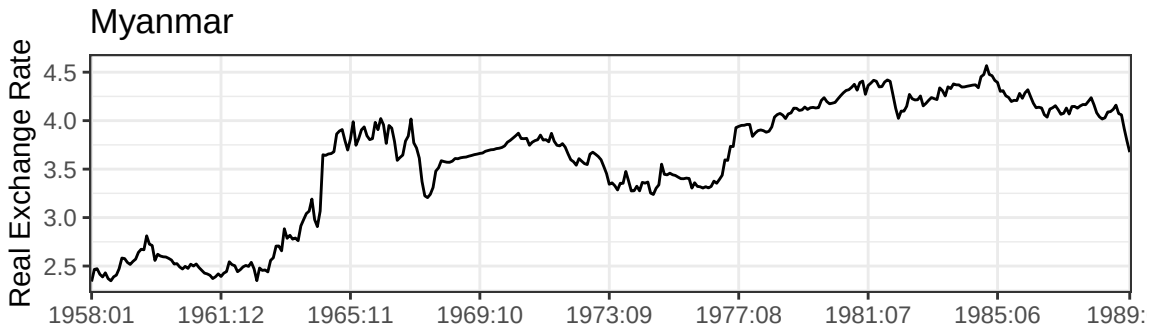

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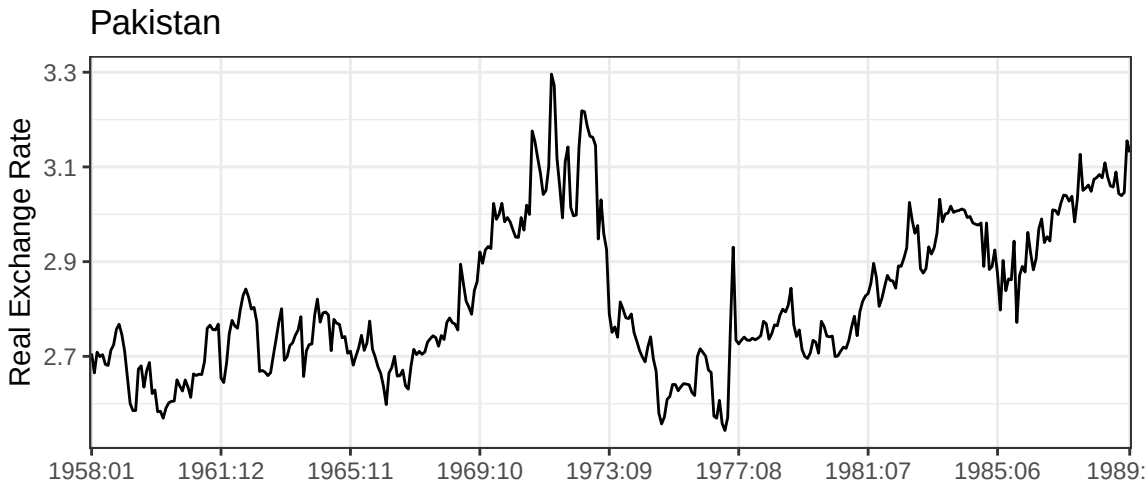

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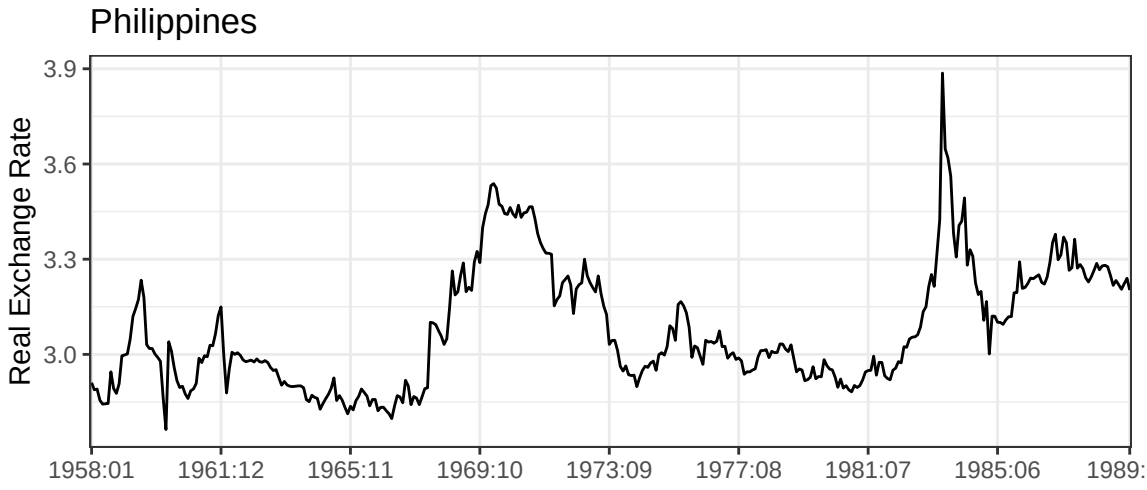

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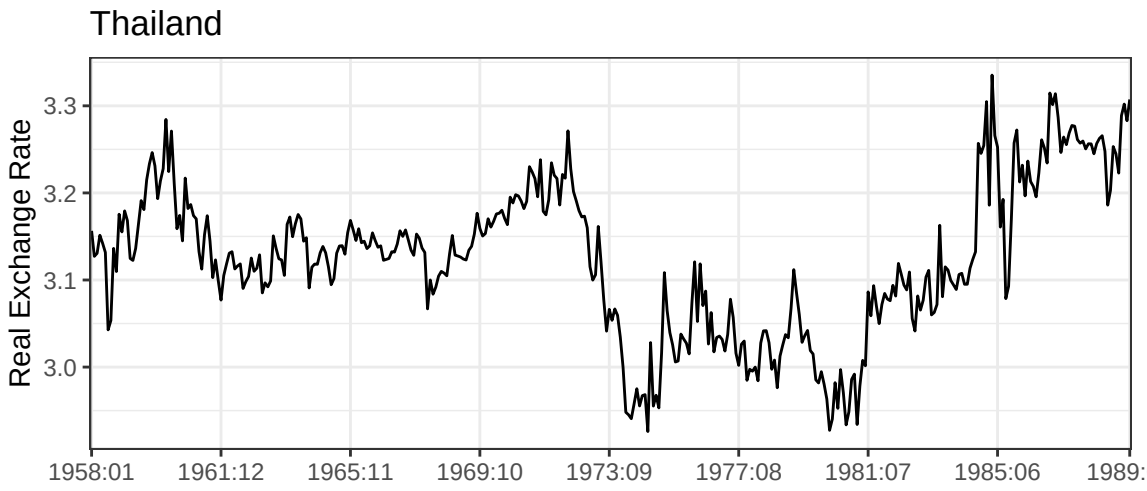

Source: Own Calculations

Figure 3.1: Plot of Real Exchange Rates over Time

3.1. Wald-Wolfowitz Tests

The Wald-Wolfowitz test is a nonparametric test that discriminates between the underlying distributions of the Bretton Woods and post Bretton Woods real exchange rates. Essentially it tests whether two random samples are from populations with the same distribution (this is the null hypothesis), or whether the two samples descend from populations with different distributions (the alternative hypothesis).[5]

The critical values for this test at 1% and 5% are 2.58 and 1.96 respectively. 3.1 shows that the tests reject the null hypothesis at a 1% significance level for all the countries. These results imply that the Bretton Woods real exchange rates descend from a population that follows a distribution that may differ in skewness, kurtosis and dispersion from that of the post Bretton Woods real exchange rates' population distribution. This suggests that it is important to include the Bretton Woods period in our analysis of real exchange rates. Luintel (2000: 169) reports smaller test statistics, but rejects the null comfortably for all of the countries.

Table 3.1: Wald-Wolfowitz tests

Test/Country	India	SriLanka	Malaysia	Myanmar	Pakistan	Philippines	Thailand
Wald-Wolfowitz	-16.07	-18.54	-17.10	-18.23	-16.27	-17.10	-15.96

4. Unit Root Tests

We can define relative PPP as:

$$\Delta s_t = \Delta p_t - \Delta p_t^*$$

This relationship shows that the percentage change in the nominal exchange rate should be equal to the difference in inflation between the domestic and foreign country. The real exchange rate (q_t) is given by:

$$q_t = s_t - p_t + p_t^*$$

From 4 we can see that the real exchange rate should be zero or a constant if PPP holds continuously. To test whether PPP holds, we can test whether the real exchange rate is stationary. Luintel (2000) argues that the power of unit-root tests is significantly higher when using a panel data set as opposed to a univariate time series. The first panel unit-root test that Luintel (2000) runs is the Augmented Dickey-Fuller test, which fails to reject the null hypothesis (there exists a unit root, and therefore the process is nonstationary) for all the countries. The only exception is for Pakistan in the post Bretton Woods period. My replicated test show similar results in 4.1, with all countries failing to reject the

[5] Luintel (2000: 169) gives the mathematical details of the test.

null. Both Luintel (2000) and my tests include a time trend, but the non-stationary results hold when excluding this trend.

However, the Dickey-Fuller tests are known for their low power, where low statistical power means we have a lower probability that the test correctly rejects the null hypothesis. Thus, Luintel (2000) proposes

Table 4.1: Augmented Dickey-Fuller Tests

Countries	Full Sample	Bretton Woods (1958:1-1973:3)	Post-Bretton Woods (1973:4-1989:6)
India (Rupee)	-2.70	-2.07	-3.66
Sri Lanka (Rupee)	-3.22	-2.11	-2.44
Malaysia (Ringgit)	-1.47	-2.16	-3.77
Myanmar (Kyat)	-1.53	-1.71	-0.16
Pakistan (Rupee)	-3.35	-2.97	-5.91
Phillipines (Peso)	-3.09	-2.07	-3.38
Thailand (Baht)	-2.44	-3.36	-3.93

As noted by Breitung & Pesaran (2005: 18), when using country data for macroeconomic applications, there are often contemporaneous correlations within the time series, which is a relevant concern for testing the PPP hypothesis. There may be unobserved common factors or spatial spillover effects, which need to be accounted for in the unit root test. Modelling cross section dependence in panel data sets is still an emerging field, but Pasaran, Im & Shin (1997) suggest that the appropriate test statistic is the T-bar test based on cross-sectional demeaned regressions. This is the approach that I take below (Im-Pesaran-Shin T-bar test), and the test rejects the null hypothesis at a 1% level, both when including and excluding a trend. This supports the results of Luintel (2000: 173). I use the same lags as Luintel (2000) for the first IPS T-bar test, are for the full sample: Malaysia(l) and Thailand(1), for the Bretton Woods period: Thailand(1), and for the post Bretton Woods period: Malaysia(l) and Thailand(1).

The first unit root test I employ is the Im-Pesaran-Shin t-bar test to replicate Luintel (2000) test. The results below show that the null hypothesis (there exists a unit root) is rejected at the conventional levels of significance[6] 4.2 -2.86 5% -2.66

[6]I found out this is a fancy way of saying reject at 1% and 5%

Table 4.2: IPS Panel Unit Root Tests (Tbar)

Period	Test	T-statistic	Trend
Full Sample	IPS	-2.97	Yes
	IPS	-2.56	No
Bretton Woods	IPS	-2.47	Yes
	IPS	-1.74	No
Post Bretton Woods	IPS	-2.53	Yes
	IPS	-2.65	No

I then tests for unit roots using LLL test (I used the package by Millo (2017) for this).

The function panel_test performs a test on a multivariate (panel) time series by testing the null hypothesis that all series have a unit root. A rejection is typically interpreted as evidence that a 'significant proportion' of the series is stationary, although how large that proportion is - or which series are stationary - is not given by the test. The test is based on averaging the individual test statistics, also called the Group-Mean (GM) test in Palm, Smeekes and Urbain (2011).

5. Variance Ratio Test

The following table shows results of the Variance Ratio test for the full sample for up to 20 months. The results of the variance ratio test for the Bretton Woods period and post Bretton Woods period (for up to 20 months[7]) can be found in the Appendix (6)

Table 5.1: Variance Ratio Test for Full Sample Up to month 20

Months	India	SriLanka	Malaysia	Myanmar	Pakistan	Philippines	Thailand
1	1.00	1.00	1.00	1.00	1.00	1.00	1.00
se	0.10	0.10	0.10	0.10	0.10	0.10	0.10
2	1.00	0.95	0.79	1.04	0.91	0.91	0.74
se	0.10	0.10	0.10	0.10	0.10	0.10	0.10
3	1.02	0.86	0.79	1.05	0.81	0.86	0.68
se	0.10	0.10	0.10	0.10	0.10	0.10	0.10
4	1.01	0.87	0.75	1.00	0.71	0.82	0.58

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[7]The results for 190 months is available upon request; it has been omitted purely to save space

Table 5.1: Variance Ratio Test for Full Sample Up to month 20

Months	India	SriLanka	Malaysia	Myanmar	Pakistan	Philippines	Thailand
se	0.10	0.10	0.10	0.10	0.10	0.10	0.10
5	0.95	0.89	0.73	0.98	0.65	0.80	0.52
se	0.10	0.10	0.10	0.10	0.10	0.10	0.10
6	0.91	0.90	0.73	0.95	0.61	0.77	0.48
se	0.10	0.10	0.10	0.10	0.10	0.10	0.10
7	0.86	0.91	0.69	0.93	0.58	0.76	0.44
se	0.10	0.10	0.10	0.10	0.10	0.10	0.10
8	0.83	0.90	0.69	0.92	0.56	0.77	0.42
se	0.10	0.10	0.10	0.10	0.10	0.10	0.10
9	0.81	0.89	0.66	0.90	0.53	0.81	0.40
se	0.10	0.10	0.10	0.10	0.10	0.10	0.10
10	0.81	0.88	0.63	0.89	0.50	0.79	0.39
se	0.10	0.10	0.10	0.10	0.10	0.10	0.10
11	0.81	0.88	0.61	0.91	0.49	0.79	0.37
se	0.10	0.10	0.10	0.10	0.10	0.10	0.10
12	0.83	0.88	0.57	0.95	0.46	0.78	0.37
se	0.10	0.10	0.10	0.10	0.10	0.10	0.10
13	0.86	0.87	0.57	0.96	0.47	0.79	0.37
se	0.10	0.10	0.10	0.10	0.10	0.10	0.10
14	0.88	0.87	0.57	0.98	0.48	0.79	0.37
se	0.10	0.10	0.10	0.10	0.10	0.10	0.10
15	0.90	0.88	0.57	1.00	0.48	0.80	0.37
se	0.10	0.10	0.10	0.10	0.10	0.10	0.10
16	0.92	0.88	0.57	1.02	0.49	0.79	0.37
se	0.10	0.10	0.10	0.10	0.10	0.10	0.10
17	0.92	0.89	0.58	1.03	0.49	0.78	0.36
se	0.10	0.10	0.10	0.10	0.10	0.10	0.10
18	0.92	0.88	0.59	1.04	0.49	0.77	0.36
se	0.10	0.10	0.10	0.10	0.10	0.10	0.10
19	0.91	0.88	0.60	1.05	0.50	0.76	0.36
se	0.10	0.10	0.10	0.10	0.10	0.10	0.10
20	0.90	0.87	0.62	1.08	0.52	0.75	0.36
se	0.10	0.10	0.10	0.10	0.10	0.10	0.10

6. Conclusion

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Appendix

Table 6.1: Variance Ratio Test for Bretton Woods period up to month 20

Months	India	SriLanka	Malaysia	Myanmar	Pakistan	Philippines	Thailand
1	1.00	1.00	1.00	1.00	1.00	1.00	1.00
se	0.15	0.15	0.15	0.15	0.15	0.15	0.15
2	1.06	0.88	0.80	1.03	1.01	1.02	0.79
se	0.15	0.15	0.15	0.15	0.15	0.15	0.15
3	1.03	0.80	0.73	1.01	0.92	0.90	0.72
se	0.15	0.15	0.15	0.15	0.15	0.15	0.15
4	0.99	0.77	0.66	0.95	0.76	0.84	0.61
se	0.15	0.15	0.15	0.15	0.15	0.15	0.15
5	0.92	0.79	0.59	0.93	0.61	0.81	0.50
se	0.15	0.15	0.15	0.15	0.15	0.15	0.15
6	0.88	0.80	0.56	0.91	0.55	0.79	0.47
se	0.15	0.15	0.15	0.15	0.15	0.15	0.15
7	0.84	0.80	0.53	0.90	0.50	0.79	0.39
se	0.15	0.15	0.15	0.15	0.15	0.15	0.15
8	0.82	0.80	0.55	0.89	0.49	0.81	0.36
se	0.15	0.15	0.15	0.15	0.15	0.15	0.15
9	0.80	0.80	0.55	0.88	0.44	0.83	0.36
se	0.15	0.15	0.15	0.15	0.15	0.15	0.15
10	0.80	0.78	0.56	0.87	0.39	0.82	0.36
se	0.15	0.15	0.15	0.15	0.15	0.15	0.15
11	0.79	0.78	0.56	0.90	0.36	0.81	0.37
se	0.15	0.15	0.15	0.15	0.15	0.15	0.15
12	0.80	0.78	0.53	0.96	0.34	0.82	0.35
se	0.15	0.15	0.15	0.15	0.15	0.15	0.15
13	0.83	0.76	0.53	0.98	0.35	0.84	0.35
se	0.15	0.15	0.15	0.15	0.15	0.15	0.15
14	0.86	0.74	0.55	1.00	0.36	0.85	0.34
se	0.15	0.15	0.15	0.15	0.15	0.15	0.15
15	0.90	0.74	0.56	1.04	0.35	0.87	0.32
se	0.15	0.15	0.15	0.15	0.15	0.15	0.15
16	0.88	0.72	0.56	1.07	0.34	0.87	0.31
se	0.15	0.15	0.15	0.15	0.15	0.15	0.15
17	0.89	0.71	0.56	1.09	0.33	0.87	0.30
se	0.15	0.15	0.15	0.15	0.15	0.15	0.15
18	0.89	0.71	0.56	1.10	0.34	0.88	0.31

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Table 6.1: Variance Ratio Test for Bretton Woods period up to month 20

Months	India	SriLanka	Malaysia	Myanmar	Pakistan	Philippines	Thailand
se	0.15	0.15	0.15	0.15	0.15	0.15	0.15
19	0.87	0.70	0.57	1.11	0.35	0.88	0.31
se	0.15	0.15	0.15	0.15	0.15	0.15	0.15
20	0.84	0.69	0.58	1.15	0.36	0.89	0.32
se	0.15	0.15	0.15	0.15	0.15	0.15	0.15

Table 6.2: Variance Ratio Test for post Bretton Woods period up to 20 months

Months	India	SriLanka	Malaysia	Myanmar	Pakistan	Philippines	Thailand
1	1.00	1.00	1.00	1.00	1.00	1.00	1.00
se	0.14	0.14	0.14	0.14	0.14	0.14	0.14
2	0.95	1.01	0.78	1.05	0.78	0.85	0.71
se	0.14	0.14	0.14	0.14	0.14	0.14	0.14
3	0.99	0.91	0.80	1.14	0.68	0.84	0.66
se	0.14	0.14	0.14	0.14	0.14	0.14	0.14
4	0.98	0.93	0.75	1.14	0.61	0.82	0.58
se	0.14	0.14	0.14	0.14	0.14	0.14	0.14
5	0.93	0.94	0.76	1.12	0.60	0.81	0.53
se	0.14	0.14	0.14	0.14	0.14	0.14	0.14
6	0.88	0.94	0.73	1.06	0.54	0.78	0.49
se	0.14	0.14	0.14	0.14	0.14	0.14	0.14
7	0.82	0.94	0.69	1.02	0.50	0.76	0.45
se	0.14	0.14	0.14	0.14	0.14	0.14	0.14
8	0.77	0.92	0.68	1.00	0.45	0.76	0.44
se	0.14	0.14	0.14	0.14	0.14	0.14	0.14
9	0.75	0.89	0.62	0.98	0.40	0.81	0.40
se	0.15	0.15	0.15	0.15	0.15	0.15	0.15
10	0.75	0.86	0.60	0.98	0.39	0.79	0.38
se	0.15	0.15	0.15	0.15	0.15	0.15	0.15
11	0.75	0.85	0.55	0.98	0.38	0.79	0.34
se	0.15	0.15	0.15	0.15	0.15	0.15	0.15
12	0.76	0.84	0.51	0.99	0.37	0.78	0.33
se	0.15	0.15	0.15	0.15	0.15	0.15	0.15
13	0.76	0.82	0.47	1.00	0.39	0.78	0.32
se	0.15	0.15	0.15	0.15	0.15	0.15	0.15
14	0.75	0.83	0.45	0.99	0.40	0.77	0.32

Continued on next page

Table 6.2: Variance Ratio Test for post Bretton Woods period up to 20 months

Months	India	SriLanka	Malaysia	Myanmar	Pakistan	Philippines	Thailand
se	0.15	0.15	0.15	0.15	0.15	0.15	0.15
15	0.73	0.83	0.43	0.98	0.39	0.77	0.31
se	0.15	0.15	0.15	0.15	0.15	0.15	0.15
16	0.72	0.83	0.42	0.99	0.39	0.75	0.31
se	0.15	0.15	0.15	0.15	0.15	0.15	0.15
17	0.72	0.83	0.42	0.98	0.38	0.74	0.30
se	0.15	0.15	0.15	0.15	0.15	0.15	0.15
18	0.71	0.81	0.42	0.98	0.38	0.72	0.28
se	0.15	0.15	0.15	0.15	0.15	0.15	0.15
19	0.68	0.80	0.42	0.99	0.38	0.70	0.27
se	0.15	0.15	0.15	0.15	0.15	0.15	0.15
20	0.64	0.78	0.41	0.99	0.39	0.68	0.25
se	0.15	0.15	0.15	0.15	0.15	0.15	0.15