Are Real Exchange Rates Stationary?
More Evidence from Panel Unit Root Tests

by

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Working Paper Series 96-01

DEPARTMENT OF ECONOMICS
THE UNIVERSITY OF NEW BRUNSWICK
FREDERICTON, CANADA

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April 1996

Financial Support from the Social Sciences and Humanities Research Council of Canada is gratefully acknowledged. I also thank Yangru Wu and Alex Hoffmeister for providing their panel unit root programmes.

Abstract

A number of recent studies using the panel unit root test of Levin and Lin (1992) suggest that real exchange rates are mean-reverting. These findings are at odds with traditional univariate unit root/stationarity test results. The purpose of this note is to extend the analysis to indexes of real effective exchange rates, and to demonstrate the sensitivity of the results to the lag lengths adopted in the panel testing procedure and the variables included in the panel. The empirical findings suggest the evidence in favour of a Cassellian view of purchasing power parity is less conclusive than it may appear.

I Introduction

The Cassellian view of PPP suggests that while absolute PPP might not hold in the short-run because of imperfections, intervention, and rigidities, the exchange rate should gravitate towards its PPP rate in a manner consistent with relative PPP.[1] Univariate tests of whether real exchange rates are mean-reverting typically suggest that real exchange rates do not exhibit a tendency to return to their sample means. This bodes ill for proponents of purchasing power parity (PPP), since it implies that long-run currency depreciation is not directly associated with differences in relative inflation rates. However, there are several recent studies based on the panel unit root tests of Levin and Lin (1992) that indicate real exchange rates are mean-reverting, thereby breathing new life into Cassellian PPP.

The purpose of this paper is to determine whether these results hold for real effective exchange rate indexes maintained by the International Monetary Fund. Previous studies are based on real exchange rates constructed using CPI and WPI data, with comparison against the United States as a base. While for some countries trade flows are dominated by the U.S., for many developing countries that is not the case - so the use of a real effective exchange rate index that takes into account differences in trading relations, unit costs, and prices across countries might provide a more telling picture of the empirical evidence on the Cassellian view.

To anticipate the results, the panel testing procedures are shown to be sensitive to the lag structure implemented in the testing routine, as is the case with traditional univariate tests for unit roots and stationarity. Moreover, the evidence on developing countries is not as favourable to PPP as that on developed countries. In addition, the panel test results are sensitive to the number of countries included in the panel - akin to the findings that causality and cointegration tests are sensitive to the variables included in the testing regime.

The next section briefly reviews absolute and relative PPP, and presents the panel unit root test of Levin and Lin (1992). This is followed by a discussion of the empirical results. Final remarks follow.

II PPP and the Panel Unit Root Test

The law of one price (absolute PPP) suggests that the prices of homogenous tradeable goods will be arbitraged such that $P_t = S_t P^*_t$,where P_t is the price of the domestic good, S_t is the exchange rate (domestic currency units per unit of foreign currency), and P^*_t is the price of the foreign good. Noting that trade impediments and transportation costs can drive a "wedge" between domestic and foreign prices, yet assuming these effects to be constant over time, one arrives at the typical logarithmic representation of PPP in equation (1), where

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[1] MacDonald (1995) suggests this view is closest to that of Cassel - hence its attribution.

lower case letters denote natural logarithms and γ captures the fixed "wedge" effects.

$$p_t = \gamma + s_t + p^*_t \tag{1}$$

A less restrictive view of the price setting process examines how equation (1) evolves over time, and is usually discussed under the rubric of relative PPP, where Δ denotes the first-difference operator:

$$\Delta p_t = \Delta s_t + \Delta p^*_t \tag{2}$$

MacDonald (1995) argues that the Cassellian view of relative PPP is consistent with the notion that while absolute and relative PPP do not hold exactly, they do provide an anchor to which the exchange rate is attracted. Thus, rearranging (2) and allowing for a stationary fluctuation about which relative PPP deviates (ϵ_t), one arrives at the hypothesis that the real exchange rate should be a stationary fluctuation, as in equation (3). One may further hypothesize that the real exchange rate is trend-stationary, in which equation (3) would be adjusted to allow for a trending mean.

$$\{\Delta p_t - \Delta s_t - \Delta p^*_t\} = \epsilon_t \tag{3}$$

Univariate tests of whether the real exchange rate is mean-reverting are not supportive of this view, and the results of cointegration-based tests of the stationarity of the real exchange rate are mixed. MacDonald (1995) provides a useful summary of the some of the empirical evidence.

Undaunted by evidence against a theory for which economists have strong priors, several researchers have revisited the empirics with the view to adjusting test statistics for effects that may have led to conclusions that real exchange rates were non-stationary (or that there was little evidence of significant cointegration between domestic prices, foreign prices, and the exchange rate). Cheung et al (1995), Culver and Papell (1995), and Dropsy (1996) employ cointegration tests that allow for realignment effects or structural breaks, and find support for PPP over a wide range of countries and time periods. Additionally, MacDonald (1996) and Wu (1996) extended unit root testing to panel unit root tests to determine whether real exchange rates are stationary. For the most part, they find the data to be consistent with PPP. We now turn to a discussion of their testing procedures.

Panel Unit Root Tests

The panel unit root test pools cross-section and time series data to determine whether each member of the panel contains a unit root against the alternative that they are jointly stationary. Levin and Lin (1992) have demonstrated that the panel unit root test can be more powerful than univariate unit root tests - the intuition is that the null hypothesis imposes cross-equation restrictions which may increase the power of the test.

Consider a group of N individuals over T periods: y_{it}, $i=1,2,\ldots,N$, $t=1,2,\ldots,T$.

$$y_{it} = \rho \, y_{it-1} + \delta_0 + \delta_1 t + \eta_i + \nu_t + \epsilon_{it} \qquad (4)$$

where η_i is the individual-specific effect, ν_t is the time-specific effect, and ϵ_{it} a stationary disturbance (assumed to be independent random variables). The Levin and Lin (1992) test is a t-statistic that examines the null that the series y_t contains a unit root for all N individuals, ie, $\rho = 1$. Wu (1996) provides an insightful description of the computational algorithm. Essentially one filters the data of constant, trend, individual-specific, and time-specific effects, and runs a panel regression of the filtered series against its lag. Serial correlation can be addressed either through non-parametric adjustments to the covariance matrix a la Phillips-Perron type tests, or the inclusion of lagged differences a la ADF type tests. For present purposes the ADF-type testing procedure will be adopted, using Akaike's information criterion (AIC) and ad hoc criteria as guides to model selection.

The limiting distribution of the test statistic is non-central normal, and since its finite sample distribution differs from its asymptotic distribution, following Wu (1996), we use Monte Carlo methods to simulate the critical values of the test statistic specific to our experiments.

III Empirical Results

Frenkal and Rose (1995), MacDonald (1996), and Wu (1996) employed the Levin and Lin (1992) panel test on real exchange rates calculated from CPI and WPI data for a number of OECD countries. Wu (1995) provided monthly, quarterly, and annual test results that uniformly rejected the null of a unit root across all three data frequencies. MacDonald (1996) reported test results on annual data, and was able to reject the null of a unit root on a panel of OECD countries.

One potential drawback to these results is that they assume the real exchange rate is relative to the United States, and while for many developed countries this may not unfairly represent the importance of trade with the U.S., it is clearly inappropriate for many developing countries whose trade is more regionally based. To address these issues, indexes of real effective exchange rates are used to determine whether or not real exchange rates are mean-reverting. All data was taken from the International Financial Statistics database of March 1995 and covers monthly data from January 1979 to December 1993, inclusive. Data at quarterly and annual frequencies is based on the monthly data.

Figure 1 plots the logarithms of the monthly real effective exchange rates for two OECD countries; Canada, and France, while figure 2 plots monthly effective exchange rates for two developing countries: Malawi, and the Philippines. In each case it appears the real effective exchange rates fluctuate considerably from their sample means. The interesting question that the Levin and Lin (1992) test addresses is whether taken together in a panel sense, do the series revert to their means?

OECD Results

Table 1 contains univariate unit root and stationarity tests for a sample of 20 OECD countries. It is clear that at the five percent level, with few exceptions, all real effective exchange rates contain a unit root using ADF tests (with and without trend), and that the series are not stationarity using KPSS tests (with and without trend). This is true for monthly, quarterly, and annual data, with very few exceptions.

Table 2 contains results based on the panel unit root test. Across all frequencies using both the AIC and an ad hoc criterion on which to choose the lag lengths in the test (to correct for serial correlation), the null of a unit root is rejected at the five percent level. The critical 5% value was obtained by Monte Carlo simulation with 10,000 replications. A byproduct of the simulations was an estimate of the small sample bias of the estimated value of ρ. Hence Table 2 also contains a "bias-adjusted" value of the autocorrelation coefficient. The estimated half-life of a one-time shock to the real effective exchange rates is consistent with other estimates in the literature - approximately 3-4 years - after correcting for small sample bias. These speeds of adjustment on OECD countries are somewhat slower than those reported by Wu (1996) using CPI and WPI data, but in line with those reported by Frankel and Rose (1995).

Developing Countries

For the sake of brevity, univariate unit root and stationarity tests for a sample of 44 developing countries will not be reported. As was the case with the OECD countries, in very few cases does one conclude that the real effective exchange rates are mean-reverting at the five percent level of significance.[2]

Table 3 presents panel unit root test results using the AIC and an ad hoc criterion (24 lags on monthly data, 8 lags on quarterly data, and 2 lags on annual data) on which to choose the lag length in the testing routine. Unlike results reported by Wu (1996), lag length selection ***does*** determine the outcome of the testing routine. Across all frequencies, the AIC selects a model without adjustment for serial correlation, and in those cases, the monthly and

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[2] These results are available from the author on request. Unit root tests allowing for possible trend breaks on many of the countries considered here are contained in Kumar and Sephton (1995).

quarterly estimates indicate that the real effective exchange rates are mean-reverting. The annual data based on the AIC criterion do not conform to this finding, at the five percent level. This may be a statistical artifact and reflect more on the methods used to construct indexes of real effective exchange rate for developing countries, where the relative lack of currency of data and its quality may affect estimates of monthly and quarterly figures. For the AIC based tests, the half-life of a shock to the real effective exchange rate is anywhere from 3.5-6.6 years, depending on data frequency - somewhat longer than in the OECD countries.

When one adopts an ad hoc criterion to select lag lengths, across all frequencies one does not reject the null that the series contain a unit root. This result is at odds with that reported on developed country data, but it may be consistent with the view that developing countries face a greater number of impediments to trade, and hence to PPP. Under these conditions, the half-life of a shock to the real effective exchange rates appears to be in the order of 2-4 years.

European Monetary System

Cheung et al (1995) examine PPP under the EMS using cointegration methods, focusing on Belgium, France, Germany, Italy, and the Netherlands. Using methods that take realignment and finite sample bias into account, they conclude that the data appears to be consistent with PPP. Since these countries were included in the OECD results above, it is interesting to determine whether the analysis of these five countries in isolation yields results different from those previously reported. Table 4 presents the panel unit root test results, for both the AIC and the ad hoc model selection criteria. Using the AIC one concludes that the series are mean-reverting, at each frequency. Estimated speeds of adjustment are from 2.8 to 5.4 years - somewhat higher than the 20 country results reported above.

When an ad hoc criterion is used to select the lag length (24 lags on monthly data, 8 lags on quarterly data, and 2 lags on annual data), *inferences are almost exactly the opposite*. In these cases the real effective exchange rates are not found to be mean-reverting on monthly or quarterly data, while with annual data one barely rejects the null at the five percent level. Estimated half-lives are somewhat shorter for the ad hoc criterion than the AIC based estimates.

IV Final Remarks

Recent studies based on panel unit root tests suggest that real exchange rates are mean-reverting. When applied to indexes of real effective exchange rates, panel unit root tests indicate that for developed countries, the data is consistent with PPP, at both monthly, quarterly, and annual frequencies. Whether a statistical artifact or by data construction, the picture for developing countries is less clear, with choice of lag length in the testing routine and data frequency affecting the outcome of the panel unit root test. The evidence in favour of PPP for the developing countries considered here is less encouraging.

Possible extensions might consider the simulation of critical values for a number of panel unit root processes containing serial correlation to act as a gauge against which to select lag lengths. Alternatively, non-parametric adjustments to the covariance matrix could provide a solution to the problem of serial correlation, although in practice, univariate tests for unit roots and stationarity have been shown to be fragile in this direction. Additionally, extension to a larger number of countries, perhaps along geographic regions as in Kumar and Sephton (1995) may provide additional information on the mean-reverting properties of real effective exchange rates.

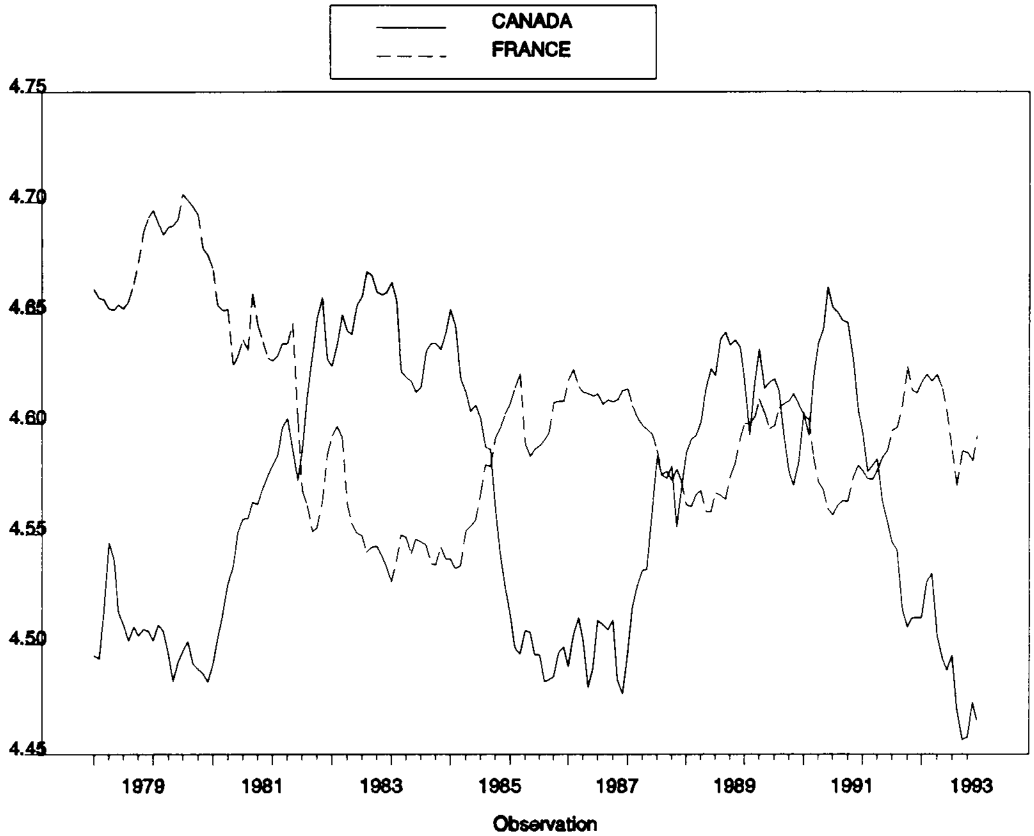

Figure 1: Real Effective Exchange Rates

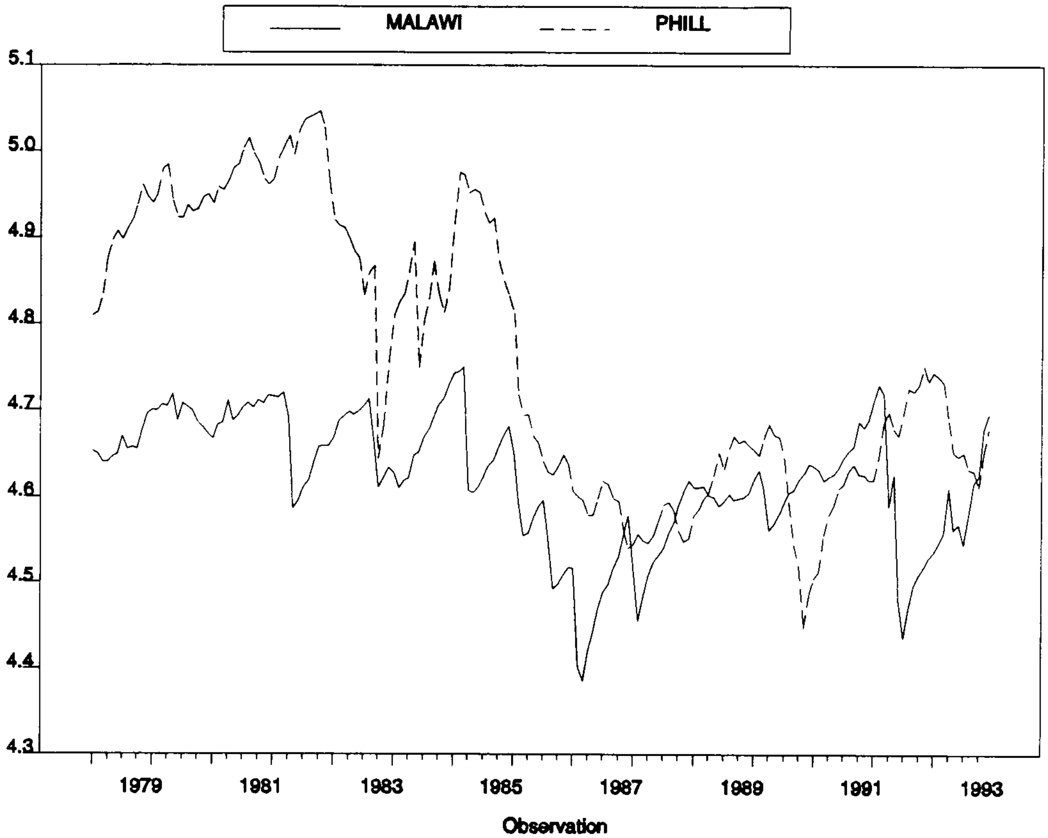

Figure 2: Real Effective Exchange Rates

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Table 1: Univariate Unit Root and Stationarity Tests - Developed Countries

	Monthly		Quarterly		Annual	
Country	ADF	KPSS	ADF	KPSS	ADF	KPSS
Austria	-0.91/-2.86	2.04/0.20	-1.93/-2.30	0.53/0.14	-2.71/-3.32	0.24/0.11
Belgium	-2.72/-2.37	0.61/0.45	-0.97/-2.36	1.27/0.12	0.01/-2.39	0.56/0.11
Canada	-1.36/-1.26	0.19/0.18	-0.66/-2.35	1.16/0.24	-3.44/-5.29	0.13/0.08
Germany	-2.69/-2.30	0.49/0.36	-1.66/-2.50	0.91/0.26	-2.24/-2.50	0.23/0.09
Denmark	-2.07/-2.96	0.89/0.32	-1.47/-1.73	1.08/0.25	-0.77/-2.05	0.43/0.10
Spain	-2.03/-2.69	0.95/0.45	-0.16/-2.26	1.10/0.10	-1.07/-1.26	0.17/0.16
Finland	-1.40/-0.79	0.49/0.35	-1.79/-2.11	0.87/0.21	-0.51/-2.76	0.52/0.10
France	-1.95/-1.88	0.71/0.34	0.43/-2.36	1.06/0.22	-2.22/-3.45	0.46/0.12
U.K.	-2.87/-3.37	0.47/0.18	-2.63/-2.32	0.34/0.29	-1.32/-2.75	0.55/0.09
Greece	-2.35/-2.08	0.78/0.52	-1.96/-2.22	0.40/0.13	-0.81/-1.47	0.27/0.15
Ireland	-2.44/-2.37	1.27/0.42	-1.79/-2.65	0.84/0.13	-2.34/-3.70	0.17/0.09
Italy	-1.21/-0.38	1.59/0.21	-1.72/-1.61	0.29/0.25	-1.54/ 1.83	0.15/0.15
Japan	-1.12/-2.98	1.73/0.19	-2.97/-2.26	0.58/0.17	0.18/-1.73	0.57/0.14
Luxembourg	-3.19/-2.35	1.01/0.51	-1.36/-2.24	1.23/0.11	-0.94/-6.75	0.56/0.10
Netherlands	-3.13/-2.93	1.12/0.24	-1.77/-2.04	0.88/0.22	-2.61/-3.10	0.45/0.13
Norway	-2.39/-2.28	0.33/0.32	-1.36/-2.69	1.08/0.12	-2.53/-1.98	0.29/0.15
Portugal	-1.09/-1.80	1.41/0.49	-2.28/-2.21	0.25/0.24	-2.90/-4.72	0.43/0.08
Sweden	-1.55/-1.63	0.33/0.32	-0.96/-2.32	0.23/0.23	-0.96/-2.15	0.58/0.11
Switzerland	-2.39/-3.57	1.00/0.07	-2.28/-2.38	0.23/0.23	3.25/ 3.68	0.54/0.15
USA	-1.27/-1.95	0.94/0.47	-0.44/-2.67	1.24/0.15	-0.30/-2.25	0.56/0.09
Critical 5% Values	-2.88/-3.44	0.46/0.15	-2.91/-3.49	0.47/0.15	-3.08/-3.76	0.49/0.15

Note: Tests are in the form (constant/constant and trend), where ADF denotes the Augmented Dickey-Fuller unit root test using the AIC to select the lag length in the test, and KPSS denotes the Kwiatkowski et al (1993) test for stationarity (using 6 lags on monthly data, 4 lags on quarterly data and 2 lags on annual data to correct for serial correlation). Critical five percent values of the ADF and KPSS tests are derived from MacKinnon (1991) and Sephton (1995), respectively.

Table 2: Panel Unit Root Test Results : 20 OECD Countries

	Monthly		Quarterly		Annual	
	AIC (L=40)	Ad Hoc (L=24)	AIC (L=5)	Ad Hoc (L=8)	AIC (L=2)	Ad Hoc (L=2)
Estimated T_ρ	-7.3924	-7.5422	-7.5143	-7.7517	-7.4173	-7.4173
Estimated ρ	0.9669	0.9725	0.9124	0.8982	0.6124	0.6124
Half-life (Years)	1.7	2.1	1.9	1.6	1.4	1.4
Bias-Adjusted ρ	0.9844	0.990	0.9654	0.9512	0.8518	0.8518
Half-life (Years) (Bias-Adjusted ρ)	3.7	5.7	4.9	3.5	3.8	3.8
Simulated Distribution of Test Statistic T_ρ (10,000 replications)						
1 %	-7.7474		-7.7705		-8.1002	
2.5 %	-7.3622		-7.4592		-7.7289	
5 %	-7.0801		-7.1594		-7.4136	
10 %	-6.7621		-6.8278		-7.0805	

Note: L denotes the number of lags included in the test to "whiten" the residuals.

Table 3: Panel Unit Root Test Results : 44 Developing Countries

	Monthly		Quarterly		Annual	
	AIC (L=0)	Ad Hoc (L=24)	AIC (L=0)	Ad Hoc (L=8)	AIC (L=0)	Ad Hoc (L=2)
Estimated T_ρ	-10.8071	-9.3261	-10.4172	-9.6651	-9.9946	-8.4572
Estimated ρ	0.9667	0.9573	0.9081	0.8742	0.6842	0.6239
Half-life (Years)	1.7	1.3	1.8	1.3	1.8	1.5
Bias-Adjusted ρ	0.9838	0.9744	0.9598	0.9259	0.9008	0.8405
Half-life (Years) (Bias-Adjusted ρ)	3.5	2.2	4.2	2.3	6.6	4.0
Simulated Distribution of Test Statistic T_ρ (10,000 replications)						
1 %	-10.3248		-10.3670		-10.8099	
2.5 %	-10.0233		-10.0684		-10.4624	
5 %	- 9.7177		- 9.7765		-10.1766	
10 %	- 9.3903		- 9.4683		- 9.8298	

Note: L denotes the number of lags included in the test to "whiten" the residuals.

Table 4: Panel Unit Root Test Results : 5 OECD Countries

	Monthly		Quarterly		Annual	
	AIC (L=14)	Ad Hoc (L=24)	AIC (L=4)	Ad Hoc (L=8)	AIC (L=1)	Ad Hoc (L=2)
Estimated T_ρ	-5.0464	-4.4249	-5.1274	-4.5146	-5.3085	-4.8933
Estimated ρ	0.9694	0.9682	0.8883	0.8801	0.5317	0.4824
Half-life (Years)	1.8	1.8	1.5	1.4	1.1	1.0
Bias-Adjusted ρ	0.9894	0.9882	0.9489	0.9407	0.7768	0.7275
Half-life (Years) (Bias-Adjusted ρ)	5.4	4.9	3.3	2.8	2.8	2.2
Simulated Distribution of Test Statistic T_ρ (10,000 replications)						
1 %	-5.1091		-5.3143		-5.6704	
2.5 %	-4.7440		-4.9361		-5.1956	
5 %	-4.5278		-4.6149		-4.8281	
10 %	-4.1786		-4.2637		-4.4442	

Note: L denotes the number of lags included in the test to "whiten" the residuals.

Appendix A : Nations Included in the 44 Developing Country Panel

The following countries were included in the panel of 44 developing countries:

South Africa	Bolivia
Chile	Columbia
Costa Rica	Dominican Republic
Ecuador	Nicaragua
Paraguay	Uruguay
Venezuela	Antiga & Barbuda
Bahamas	Grenada
Guyana	Netherlands Antilles
St. Kitts	St. Lucia
St. Vincent	Trinidad and Tobago
Bahrain	Cyprus
Malaysia	The Philippines
Burundi	Cameroon
Central African Republic	Zaire
Gabon	Gambia
Cote d'Ivoire	Lesotho
Malawi	Morocco
Nigeria	Sierra Leon
Togp	Uganda
Zambia	Solomon Islands
Fiji	Papua New Guinea
Western Samoa	Hungary