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Purchasing power parity and real effective exchange rates*

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Abstract

This study re-examines the validity of Purchasing Power Parity (PPP) by focusing on the real effective exchange rates (REERs) for the post-Bretton Woods period, using newly developed unit root tests that account for both nonlinearity and smooth temporary multiple breaks in the data. The tests are applied to the REERs of 23 developed countries and are able to reject the null hypothesis of a unit root in 20 cases. The test results reveal that large swings truly exist in most of the REERs, therefore it is crucial to model these infrequent smooth temporary mean changes in the data in testing the (non)stationarity of the REERs. The study provides stronger support than most of previous studies for that PPP holds in a stricter, multi-country version during the floating exchange rate period for the majority of developed countries.

JEL classification: F31; C22

Keywords: PPP; Real effective exchange rates; Nonlinear stationarity; Smooth structural breaks

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1. Introduction and background

The Purchasing Power Parity (PPP) hypothesis argues that the real exchange rate is stationary so that the nominal exchange rate and domestic and foreign price levels of goods and services converge to a constant, long run equilibrium level over time. PPP is an important building block of many macroeconomic models and its validity has significant policy implications. Earlier studies of PPP relied on linear unit root tests, while more recent studies account for nonlinearities and/or structural breaks in real exchange rates. However, the debate on the validity of PPP is unsettled yet as the evidence for PPP has not been reliable due to conflicting empirical findings.[1] For example, in a recent study, employing unit root tests and recursive analysis, Zhou and Kutan (2011) have tested the validity of PPP using the bilateral real exchange rates against the US dollar, Japanese yen, and a European currency during the post-Bretton Woods period. They find that the results whether PPP holds or not are sensitive to employing different numeraire currencies, different sample periods covering regional and global crises and inclusion of countries with different level of economic and regional integration. Their study concludes that "…a through robustness examination (of PPP) using a battery of tests accounting for nonlinearities, the form of nonlinearities, breaks and potential other outliers should be performed in order to draw reliable inferences" (p. 2489, Zhou and Kutan, 2011).

An important recent contribution to the literature, dealing directly with the empirical issues raised in Zhou and Kutan (2011), is a study by Christopoulos and León-Ledesma (2010) which developed tests for unit roots that account *jointly* nonlinearity and temporary structural breaks, two key potential reasons for the rejection of PPP. As the real exchange rates may simultaneously exhibit temporary structural breaks and nonlinear mean reversion, the tests

[1] For recent reviews, see, among others, Taylor and Taylor, 2004; Murray and Papell, 2005; Bahmani-Oskooee and Hegery, 2009).

developed by Christopoulos and León-Ledesma (2010) is likely to yield higher power than those accounting for either nonlinear adjustment or structural breaks alone. The tests of Christopoulos and León-Ledesma (2010) allow for multiple temporary structural breaks, capturing large changes in the mean of the real exchange rate, together with nonlinear adjustment using an exponential smooth transition autoregressive (ESTAR) model introduced by Kapetanios, Shin, and Snell (2003). Using these tests, they have tested the validity of PPP based on a set of 15 US-dollar-based bilateral real exchange rates for the post-BrettonWoods flexible exchange rate era and find that that real exchange rates are stationary in 14 out of 15 cases, suggesting that PPP holds.

In this paper, we utilize both the unit root tests of Kapetanios, Shin, and Snell (hereafter, KSS) (2003), and the tests newly developed by Christopoulos and León-Ledesma (2010) to further examine the stationarity of the real effective exchange rates (REERs) of 23 developed economies, which includes 15 founding members[2] of the European Union (EU) and 8 other developed economies (Australia, Canada, Iceland, Japan, New Zealand, Norway, Switzerland, and the US), as well as a measure of the REER of 17 current euro-area countries. Our study extends the Christopoulos and León-Ledesma study in several different directions.

First, while Christopoulos and León-Ledesma (2010) employ bilateral real exchange rates, we use data on real effective exchange rates. As Bahmani-Oskooee, Kutan and Zhou (2007) argue, using REERs provides a test of the multi-country version of PPP, rather than that of PPP based on bilateral trading partners. Hence, unit root tests based on REERs provide an alternative approach to test the validity of PPP. If PPP holds based on REERs as well, then there would be a

[2] 15 EU founding members are 12 euro-zone countries, namely, Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, and 3 non-euro-zone countries: Denmark, Sweden, and the UK.

much stronger evidence for PPP to hold, confirming the findings in Christopoulos and León-Ledesma (hereafter, CL) (2010) using the bilateral rates.

Second, we utilize not only the CL tests but also the KSS tests. Both tests have the same null hypothesis of a unit root. While the alternative hypothesis of the conventional unit root is linear stationary, both KSS and CL tests allow for nonlinear stationarity in the alternative hypothesis. In addition, the CL tests account for the presence of multiple smooth temporary breaks such as large swings in the series. Hence, using both tests simultaneously we are able to detect the underlying sources of the deviations from PPP. Therefore, if the conventional tests are unable to reject the null of a unit root in REERs, while the KSS and/or CL tests reject the null hypothesis, the results may suggest that the REERs are nonlinear stationary. Moreover, if the conventional tests and KSS tests are unable to reject the null of a unit root in REERs, whereas the CL tests reject the null hypothesis, we can then conclude that PPP holds and the difference in inferences is due to the presence of multiple smooth temporary breaks in REERs.

Third, we employ data of the REER of 17 current euro-area countries. This allows us to test whether PPP holds better in an economic and monetary union area than in individual economies without any formal arrangements. In an economic area such as the euro-zone one, transaction costs may be lower, hence non-linear mean reversion in the euro-zone real exchange rate as emphasized by the transition costs literature may exhibit different characteristics than those in the non-euro-zone countries.

Fourth, our sample period (1973-2011) covers the recent global crisis, while the sample period employed in Christopoulos and León-Ledesma (2010) ends in 2006. Large changes in the value of the US dollar and other major currencies during the recent crisis provide an additional opportunity to tests the sensitivity of the results on the validity of PPP using CL tests. Finally, our country coverage (23 countries) is much broader than the one utilized in Christopoulos and León-Ledesma (2010).

This paper is organized as follows. In the section, we discuss our methodology and test procedures. In section 3, we describe our data set and present our empirical findings. The last section concludes the paper.

2. Methodology and test procedures[3]

In this section, we first discuss the KSS unit root tests, followed by the tests newly developed by Christopoulos and León-Ledesma (2010). For y_t being the logs of the REERs and u_t being the de-meaned or de-meaned and de-trended version of y_t, the KSS tests are based on the following auxiliary regression:

$$\Delta u_t = \delta u_{t-1}^3 + \sum_{j=1}^{p} \rho_j \Delta u_{t-j} + \text{error} \quad (1)$$

which is obtained from a first-order Taylor series approximation of an exponential smooth transition autoregressive (ESTAR) model specified in KSS (2003). The null hypothesis of nonstationarity to be tested with (1) is H_0: $\delta = 0$ against the alternative of (nonlinear) stationarity H_1: $\delta < 0$. The augmentations $\sum_{j=1}^{p} \rho_j \Delta u_{t-j}$ are included to correct for serially correlated errors.[4] KSS (2003) use the t-statistic for $\delta = 0$ against $\delta < 0$ and tabulated the asymptotic critical values of the test statistics via stochastic simulations.

[3] This section draws on Kapetanios, et al. (2003) and Christopoulos and León-Ledesma (2010).

[4] See Kapetanios, et al. (2003) for more details.

The tests developed by Christopoulos and León-Ledesma (2010) use trigonometric variables to capture large changes in the mean of y_t with the consideration of the following model:

$$y_t = \lambda_0 + \lambda_1 \sin\left(\frac{2\pi kt}{T}\right) + \lambda_2 \cos\left(\frac{2\pi kt}{T}\right) + v_t \qquad (2)$$

where $\lambda_0 + \lambda_1 \sin\left(\frac{2\pi kt}{T}\right) + \lambda_2 \cos\left(\frac{2\pi kt}{T}\right)$ is a form of Fourier function that may capture several smooth breaks of unknown form in y_t . In equation (2), k = 1, 2, 3, …, which is the number of frequencies of the Fourier function, t is a trend term, T is the sample size, and π = 3.1416. The null hypothesis with (2) is that there is a unit root in v_t and the alternative is that v_t is linear or nonlinear stationary. Note that smooth breaks represented by the Fourier functions "are temporary as the start and end values of the Fourier function are the same when k is not fractional" (CL, 2010, p.1080). If the behavior of a real exchange rate can be well modeled by such a function with an integer k, it would be consistent with having a constant mean in the long run and thus "is compatible with PPP" (CL, 2010, p.1080).

Following the suggestion of Christopoulos and León-Ledesma (2010), their tests are conducted through a three step procedure proposed in their article. Step 1 is to run an OLS regression of the logs of REER (i.e., y_t) on a constant, $\sin\left(\frac{2\pi kt}{T}\right)$, and $\cos\left(\frac{2\pi kt}{T}\right)$ for values of k between 1 and 5 and select $\tilde{k}$ that minimizes the residual sum of squares. The OLS residual series $\hat{v}_t$ is obtained for the next step. That is,

$$\hat{v}_t = y_t - \left[\hat{\lambda}_0 + \hat{\lambda}_1 \sin\left(\frac{2\pi \tilde{k}t}{T}\right) + \hat{\lambda}_2 \cos\left(\frac{2\pi \tilde{k}t}{T}\right)\right] \qquad (3)$$

The second step is to test for a unit root in $\hat{v}_t$ with the following regressions:

$$\Delta\hat{v}_t = \alpha\hat{v}_{t-1} + \sum_{j=1}^{p}\rho_j\Delta\hat{v}_{t-j} + \varepsilon_t \tag{4}$$

$$\Delta\hat{v}_t = \delta\hat{v}_{t-1}^3 + \sum_{j=1}^{p}\rho_j\Delta\hat{v}_{t-j} + \varepsilon_t \tag{5}$$

$$\Delta\hat{v}_t = \gamma\hat{v}_{t-1}[1-\exp(-\theta\Delta\hat{v}_{t-i}^2)] + \sum_{j=1}^{p}\rho_j\Delta\hat{v}_{t-j} + \varepsilon_t, \qquad i = 1, 2, \ldots, L \tag{6}$$

where ε_τ is a white noise error term. Model (4) is called Fourier-ADF (FADF) test with the alternative hypothesis of $\hat{v}_t$ being linear stationary. Model (5) is very similar to regression (1) and thus is considered as a Fourier-KSS (FKSS) test with the alternative that allows $\hat{v}_t$ being nonlinear stationary. Model (6) corresponds "to the unit root tests developed by Kilic and de Jong (2006)," (CL 2010, p. 1080). The exponential function in model 6 implies that the speed of mean reversion is faster when the REER "is far from its equilibrium value determined by the Fourier function, whereas it behaves as a unit root process when it is close" (CL 2010, p. 1082) to the equilibrium value. The test statistics, denoted as F-Sup-t_{iN} in CL (2010), are the *t*-ratio statistics for the null hypothesis of $\gamma = 0$ against the alternative of $\gamma < 0$, obtained through a procedure introduced in Christopoulos and León-Ledesma (2010).[5] The critical values of the *t*-statistic for the null of $\alpha = 0$ or $\delta = 0$ or $\gamma = 0$ against the alternative of $\alpha < 0$ or $\delta < 0$ or $\gamma < 0$,

[5] We are grateful to Miguel León-Ledesma for his help and patience in guiding us to complete the F-Sup-t_{iN} tests for the present study.

respectively, are tabulated in Christopoulos and León-Ledesma (2010) with different sample sizes via the Monte Carlo simulations.

The last step is an F-test, $F(\tilde{k})$, for the significance of λ_1 and λ_2 in equation (2) if the null of a unit root in $\hat{v}_t$ in step 2 is rejected. The null hypothesis is linearity, H_0: $\lambda_1 = \lambda_2 = 0$, against the alternative of nonlinearity, H_1: λ_1 and/or $\lambda_2 \neq 0$. A rejection of the null would indicate that the REER is stationary around some large changes in the mean of the RRER. The critical values of the $F(\tilde{k})$ statistic are taken from Table 1 of Becker et al. (2006).

The empirical investigation is conducted first by applying the conventional unit root tests, the augmented Dickey-Fuller (ADF) test and the DF test with generalized least squares method (DF-GLS) introduced by Elliott, Rothenberg, and Stock (ERS) (1996) to all REERs in the study using the model with a constant only for the sample of the post-Bretton Woods period. The KSS tests for de-meaned data and the three CL tests (i.e., FADF, FKSS, and F-Sup-t_{iN} tests) following the three-step procedure mentioned in the last few paragraphs are then exercised.

The rejection of the null of nonstationarity by some of these tests would be the evidence for the REER being level stationary. Note that a level stationary REER is consistent with PPP in a strict form. The number of augmentations *p* for either the ADF, DF-GLS, and KSS tests or the three CL tests is selected based on significance testing procedure in Ng and Perron (1995). The maximum number of *p* was set to 12 for our monthly data, and insignificant augmentation terms were excluded.[6]

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[6] It is found that the tests with a fixed number of augmentations, $p = 12$, or with selected number of augmentations yield very similar results. In other words, the results of the tests are not very sensitive to the models with a few more insignificant augmentation terms. To save space, only the results with selected number of augmentations are reported. The rest of the results are available from the authors upon request.

3. Data and test results

Being studied in this paper are the REERs of 23 developed economies, which includes 15 founding members of the European Union (EU) and 8 other developed economies (Australia, Canada, Iceland, Japan, New Zealand, Norway, Switzerland, and the US), as well as a measure of the REER of 17 current euro-area countries. Country selection is based on data availability. All the data of REERs are collected from the *OECD Economic Indicators*. The study focuses on the post-Bretton Woods floating exchange rate period. We use the logs of the monthly REER data from 1973:1 through 2011:3.

The results for the full sample period are reported in Table 1. They indicate that, among the six tests employed in the study, the F-Sup-t_{iN} test is the most powerful relative to the others.[7] At the 5% significance level, the ADF, DF-GLS, and KSS tests reject the null for 8, 8, and 9 out of the REERs of 23 countries, respectively, while the FADF and FKSS reject the null for 11 and 9 out of 23 cases, respectively. Yet the F-Sup-t_{iN} test statistics reject the null of a unit root for 17 out of 23 REERs. When looking at the 10% significance level, all of the former three tests reject the null of a unit root for 9 out of 23 REERs, whereas the FADF, FKSS, and F-Sup-t_{iN} test statistics show the rejection of the null for 14, 12, and 20 out of 23 rates, respectively. Moreover, for the REER of the euro area, the FADF and FKSS tests reject the null at the 5% significance level and the F-Sup-t_{iN} test statistics can do so at the 1% significance level, but the ADF, DF-GLS, and KSS tests can reject the null for the euro-area REER only at the 10% significant level.

These results show that most of the REERs are stationary after taking account for nonlinearity and large swings in them. The test results reveal that, because large swings seem to

[7] Christopoulos and León-Ledesma (2010) have investigated the power properties of the FADF, FKSS, and F-Sup-t_{iN} tests. They found that F-Sup-t_{iN} test was often more powerful than the other two tests.

truly exist in the REERs, when testing the (non)stationarity of the REERs, it is crucial to model these infrequent smooth temporary mean changes in the data. These findings are in support of PPP during the post-Bretton Woods period for the majority of the countries in the study.

4. Robustness tests

In this section, we compare their findings for the sample periods 1973:1-2011:3 and 1973:1-1998:12 to test whether the results are sensitive to the euro period. As the Christopoulos and León-Ledesma (2010) tests already correct for nonlinearity and smooth breaks, we expect that the breaking the sample into pre- and post-euro area would not affect our inferences reached in the previous section. The results for the sub-sample period from 1973M1 to 1998M12 are reported in Table 2. They show that, at the 5% significance level, the ADF, DF-GLS, and KSS tests reject the null for 6, 5, and 7 out of 23 REERs, respectively, while the FADF, FKSS, and F-Sup-t_{iN} tests reject the null for 8, 9, and 15 out of 23 cases, respectively. At the 10% significance level, the latter three tests reject the null of a unit root for 11, 11, and 19 out of 23 REERs, respectively. For the REER of the euro area, the ADF and KSS tests fail to reject the null, but the DF-GLS and FADF tests reject the null at the 10% significant level, while the FKSS and the F-Sup-t_{iN} tests reject the null at the 5% and 1% significance levels, respectively.

As we expected, the results imply that the conclusion that most of the REERs are linear or nonlinear stationary is not notably sensitive to whether or not the sample includes the data of the post-euro period. The study therefore provides *robust* evidence for PPP to hold in the post-Bretton Woods period for the majority of developed countries, after taking nonlinearity and large swings in the data into account.

5. Conclusions

This study re-examines the validity of PPP by focusing on the real effective exchange rates using newly developed unit root tests that account for both nonlinearity and smooth temporary multiple breaks in the data. The tests are applied to the REERs of 23 developed countries as well as the REER of 17 current euro-area countries for the post-Bretton Woods floating exchange rate period. The rejection of the null of nonstationarity in a REER may provide a multi-country version of PPP.

An important contribution of the present study is that the test results reveal that large swings truly exist in most of the REERs and they are not inconsistent with PPP. Therefore, it is crucial to model these infrequent smooth temporary mean changes in the data in testing the (non)stationarity of the REERs. Our empirical results indicate that that the majority of the REERs are stationary when nonlinearity and large swings in the data are taken into account. We find the evidence of rejecting the null of a unit root in the REERs for 17 or 20 out of 23 cases at the 5% or 10% significance levels, respectively, when the most powerful F-Sup-t_{iN} test statistics are utilized. The results are in line with Christopoulos and León-Ledesma (2010) who used a set of 15 US-dollar-based bilateral real exchange rates for the post-Bretton Woods flexible period and "reject the null of a unit root for 14 of them" (p. 1092) at the 10% significance level.

By including more countries in the study, employing additional unit root tests, using the REERs instead of bilateral real exchange rates as an alternative approach to testing PPP, and extending the sample period to very recent years including the recent financial crises in the USA and Europe etc., this paper provides a more comprehensive study on PPP than that of Christopoulos and León-Ledesma (2010). Because the finding of a stationary REER would suggest that PPP holds not only with respect to a country's bilateral trading partners but also with respect to its many trading partners, the present paper provides stronger support than almost all previous studies for that PPP holds in a stricter, multi-country version during the post-Bretton Woods period for the majority of developed countries. Our results also suggest that there is more evidence for PPP under the CL tests than the KSS tests, implying that large smooth breaks in the data may mostly account for the conclusion in previous studies that PPP may not hold.

Moreover, our robustness tests showed that empirical support for PPP by this study is not sensitive to whether or not the sample includes different sample periods such as the post-euro period. This finding is expected as the Christopoulos and León-Ledesma (2010) tests already correct for nonlinearity and smooth breaks in data. Hence, we can confidently conclude PPP can serve as a reliable framework in open-macroeconomy models.

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Table 1. Results of testing for a unit root in the real effective exchange rates (Sample period: 1973M1 – 2011M3)

	ADF	DF-GLS	KSS	$\tilde{k}$	F($\tilde{k}$)	FADF	FKSS	θ	ρ	F-Sup-t_{iN}
					EU countries: Euro area					
Austria	-3.06[b]	-0.29	-3.52[a]	1	204.76	-3.50[c]	-3.50[c]	1.73	-0.074	-4.20[b]
Belgium	-2.10	-2.10[b]	-2.04	2	94.48	-2.55	-2.41	30.10	-0.022	-2.78
Finland	-1.66	-1.65	-2.01	1	476.48	-3.73[c]	-3.32[c]	1.71	-0.078	-4.79[a]
France	-2.62[c]	-1.94[b]	-1.73	1	67.83	-3.90[b]	-3.55[c]	28.95	-0.057	-4.08[b]
Germany	-3.32[b]	-1.76[c]	-4.32[a]	2	217.21	-4.37[a]	-4.01[a]	12.00	-0.072	-4.92[a]
Greece	-1.48	-1.48	-1.16	1	376.31	-2.89	-3.30	0.46	-0.221	-4.27[b]
Ireland	-1.40	-0.78	-1.47	2	334.30	-2.46	-2.43	0.49	-0.098	-3.10[c]
Italy	-2.02	-1.99[b]	-3.54[a]	2	384.08	-3.34[b]	-5.08[a]	0.33	-0.238	-6.11[a]
Luxemburg	-1.78	-1.34	-1.72	1	152.35	-2.49	-2.67	4.19	-0.039	-3.15
Netherlands	-3.30[b]	-2.51[b]	-3.35[b]	1	116.60	-4.41[a]	-4.66[a]	4.56	-0.072	-4.69[a]
Portugal	-1.14	-0.74	-1.51	1	870.28	-3.44	-3.72[b]	1.31	-0.141	-4.71[a]
Spain	-2.18	-0.70	-2.56	3	78.54	-1.95	-1.99	0.19	-0.147	-3.07[c]
Euro Area (G17)	-2.83[c]	-1.92[c]	-2.83[c]	2	146.88	-3.33[b]	-3.45[b]	6.96	-0.053	-4.09[a]
					EU countries: Non-euro area					
Denmark	-1.93	-0.56	-2.07	1	159.67	-2.82	-3.80[b]	0.81	-0.103	-4.66[a]
Sweden	-1.75	-0.64	-2.46	1	170.38	-2.39	-2.67	1.54	-0.049	-3.39
UK	-3.00[b]	-2.67[a]	-3.48[b]	2	173.18	-3.80[b]	-4.40[a]	11.18	-0.067	-4.45[a]

Table 1 (continued)

	ADF	DF-GLS	KSS	$\tilde{k}$	F($\tilde{k}$)	FADF	FKSS	θ	ρ	F-Sup-t_{iN}
					Non-EU countries					
Australia	-2.32	-1.04	-3.60[a]	1	500.03	-3.87[b]	-3.82[b]	6.06	-0.072	-3.91[b]
Canada	-1.96	-0.95	-1.75	1	231.53	-2.72	-2.60	0.24	-0.122	-3.59[c]
Iceland	-3.06[b]	-2.97 [a]	-2.36	3	54.67	-3.77[a]	-3.61[b]	7.43	-0.083	-4.33[a]
Japan	-2.39	-0.56	-2.63	1	527.45	-3.64[c]	-3.17	16.25	-0.047	-3.92[b]
New Zealand	-3.33[b]	-2.39[b]	-4.50[a]	5	119.12	-3.15[b]	-2.15	10.22	-0.052	-3.32[b]
Norway	-3.09[b]	-2.78[a]	-4.65[a]	2	70.55	-3.70[b]	-4.72[a]	1.03	-0.138	-4.53[a]
Switzerland	-3.36[b]	-0.32	-3.21[b]	1	113.53	-3.80[b]	-2.72	4.18	-0.071	-4.25[b]
US	-2.13	-1.49	-2.02	2	255.73	-3.55[b]	-2.75	2.09	-0.069	-4.55[a]

Notes: G17 means the group of 17 current euro-zone countries. The ADF and DF-GLS test statistics are obtained by allowing a constant in the series for testing. The KSS test statistics are for de-meaned data. The 1%, 5% and 10% critical values of MacKinnon (1996) for ADF are -3.44, -2.87, and -2.57, respectively, and those for DF-GLS are -2.57, -1.94, and -1.61, respectively. The 1%, 5%, and 10% asymptotic critical values for KSS are -3.48, -2.93 and −2.66, respectively, taken from Kapetanios et al. (2003, p. 364). FADF, FKSS, and F-Sup-t_{iN} are the test statistics obtained by applying the ADF and KSS tests as well as the Sup-t_{iN} tests of Kilic and de Jong (2006) to the residual series from the regression of RER on a Fourier function. For these three test statistics, the finite sample critical values are different for the tests using the Fourier functions with different $\tilde{k}$, and they are taken from tables 1-3 in Christopoulos and León-Ledesma (2010). [a], [b] and [c] denote rejection of the null of a unit root at the 1%, 5% and 10% significance levels, respectively. F($\tilde{k}$) is attained from an F-test with the critical values given in Table 1 of Becker et al. (2006). † indicates rejection of the null of linearity at any conventional significance level.

Table 2. Results of testing for a unit root in the real effective exchange rates (Sample period: 1973M1 – 1998M12)

	ADF	DF-GLS	KSS	$\tilde{k}$	F($\tilde{k}$)	FADF	FKSS	θ	ρ	F-Sup-t_{iN}
EU countries: Euro area										
Austria	-2.35	-0.05	-3.00[b]	1	186.51	-3.52[c]	-3.21	0.23	-0.182	-4.11[b]
Belgium	-1.79	-1.79[c]	-1.91	1	94.51	-2.42	-3.23	77.85	-0.028	-2.78
Finland	-2.21	-1.53	-2.56	1	121.05	-3.34	-3.46	0.62	-0.122	-4.54[a]
France	-3.22[b]	-2.03[b]	-2.42	1	39.24	-4.12[b]	-4.55[a]	1.73	-0.163	-5.23[a]
Germany	-2.96[b]	-2.10[b]	-3.53[a]	1	175.09	-4.09[b]	-4.22[b]	15.22	-0.086	-4.72[a]
Greece	-2.28	-1.78[c]	-1.91	1	163.36	-3.26	-3.24	0.87	-0.261	-4.52[a]
Ireland	-2.15	-1.82[c]	-3.18[b]	1	364.09	-4.46[a]	-4.02[b]	1.07	-0.215	-4.35[a]
Italy	-1.67	-1.67[c]	-2.78[c]	1	202.59	-2.67	-4.05[b]	4.83	-0.087	-4.38[a]
Luxemburg	-1.45	-1.14	-1.57	1	142.83	-1.85	-2.35	0.08	-0.221	-2.93
Netherlands	-3.11[b]	-2.32[b]	-2.65	1	67.11	-3.97[b]	-4.28[b]	6.22	-0.085	-4.60[a]
Portugal	-1.16	-1.10	-2.06	1	464.91	-4.07[b]	-3.78[c]	6.89	-0.158	-4.32[a]
Spain	-2.23	-1.13	-1.63	2	87.70	-2.30	-2.04	6.35	-0.064	-3.09[c]
Euro Area (G17)	-2.19	-1.78[c]	-2.49	2	113.97	-3.24[c]	-3.43[b]	2.19	-0.082	-4.04[a]
EU countries: Non-euro area										
Denmark	-2.02	-0.88	-2.51	1	78.20	-2.97	-3.36	0.95	-0.156	-4.76[a]
Sweden	-1.58	0.67	-2.36	2	121.31	-2.61	-2.99	0.86	-0.143	-4.09[a]
UK	-2.71[c]	-2.45[b]	-2.39	3	86.52	-3.32[b]	-2.89[c]	4.10	-0.072	-3.51[b]

Table 2 (continued)

	ADF	DF-GLS	KSS	$\tilde{k}$	F($\tilde{k}$)	FADF	FKSS	θ	ρ	F-Sup-t_{iN}
					Non-EU countries					
Australia	-1.84	-0.09	-3.29[b]	1	160.40	-2.43	-2.44	1.44	-0.075	-3.23
Canada	-0.89	0.50	-0.22	2	110.17	-1.38	0.12	22.30	-0.018	-1.78
Iceland	-3.35[b]	-2.71[a]	-4.38[a]	2	51.76	-4.06[a]	-4.53[a]	5.18	-0.192	-5.09[a]
Japan	-1.68	-0.22	-2.22	1	263.33	-2.75	-3.22	6.40	-0.046	-3.32[c]
New Zealand	-3.60[a]	-1.93[c]	-4.29[a]	3	66.65	-3.55[b]	-4.49[a]	1.10	-0.141	-3.59[b]
Norway	-1.60	-1.69[c]	-2.55	1	61.29	-2.38	-2.16	5.40	-0.068	-3.33[c]
Switzerland	-3.08[b]	-0.17	-3.29[b]	1	59.09	-3.64[c]	-4.21[b]	3.63	-0.079	-4.45[a]
US	-2.22	-1.49	-1.97	2	116.02	-2.17	-2.87	5.12	-0.045	-3.16[c]

See notes to Table 1.