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Bounds tests of the theory of purchasing power parity

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Abstract

In this paper we test the absolute and relative purchasing power parity (PPP) hypotheses during the recent flexible exchange rate period, using quarterly data for 21 OECD countries. In doing so, we use a new econometric technique developed by M.H. Pesaran et al. [Bounds testing approaches to the analysis of long run relationships. University of Cambridge, Department of Applied Economics, Working Paper #9907]. This approach is particularly interesting as it is capable of testing the existence of long-run relations regardless of whether the underlying variables are stationary, integrated, or mutually cointegrated. © 2002 Elsevier Science B.V. All rights reserved.

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1. Introduction

The theory of purchasing power parity (PPP) has attracted a great deal of attention and has been explored extensively in the recent literature using recent advances in the field of applied econometrics. Based on the law of one price,

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PPP asserts that relative goods prices are not affected by exchange rates – or, equivalently, that exchange rate changes will be proportional to relative inflation. The relationship is important not only because it has been a cornerstone of exchange rate models in international economics, but also because of its policy implications – it provides a benchmark exchange rate and hence has some practical appeal for policymakers and exchange rate arbitragers.

A sufficient condition for a violation of absolute PPP is that the real exchange rate follows a random walk or, equivalently, that there is no cointegration between the nominal exchange rate and the domestic and foreign price levels. Recent advances in the field of applied econometrics (that pay explicit attention to the integration and cointegration properties of the variables) have facilitated the testing of such hypotheses. Although there is a plethora of studies testing for PPP – see, for example, the recent survey by Rogoff (1996) – the literature, however, provides mixed support for long-run PPP.

There are studies, for example, that investigate long-run purchasing power parity using tests where nonstationarity of the real exchange rate and no cointegration between the nominal exchange rate and the domestic and foreign price levels are the null hypotheses. [1] These studies generally fail to find support for long-run purchasing power parity. For example, the empirical consensus in Mark (1990), Grilli and Kaminsky (1991), Flynn and Boucher (1993), Serletis (1994), Serletis and Zimonopoulos (1997), and Dueker and Serletis (2000) is that purchasing power parity does not hold during the recent floating exchange rate period. But there are also studies, using similar tests, covering different groups of countries (see Phylaktis and Kassimatis, 1994) as well as studies covering periods of long duration (see Lothian and Taylor, 1996; Perron and Vogelsang, 1992) or country pairs experiencing large differentials in price movements (see Frenkel, 1980; Taylor and MacMahon, 1988) that report evidence of mean reversion towards PPP.

Also, studies that investigate long-run PPP using tests (developed by Kwiatkowski et al. (1992) and Shin (1994)) where stationarity and cointegration are the null, rather than the alternative hypotheses, find support of long-run PPP. Culver and Papell (1999), for example, using quarterly data from the current floating exchange rate period for 21 industrialized countries, provide evidence of long-run PPP. In particular, they cannot reject either the null hypothesis of stationarity of the real exchange rate or the null of cointegration between the nominal exchange rate and the domestic and foreign price levels. There are also

[1] The most commonly used unit root tests are the augmented Dickey–Fuller (ADF) (see Dickey and Fuller, 1981), the nonparametric, $Z(t_{\hat{\alpha}})$, test of Phillips (1987) and Phillips and Perron (1988), the Perron (1989) and Perron and Vogelsang (1992) tests, and the fractional unit root test of Sowell (1992). The most commonly used cointegration tests are the Engle and Granger (1987) two-step test, Johansen's (1988) maximum likelihood generalization of the Engle and Granger (1987) test, and the Cheung and Lai (1993) fractional cointegration test.

studies that use panel data procedures, in order to gain power by exploiting both cross-sectional and time series variation. For example, Abuaf and Jorion (1990), Frankel and Rose (1996), Jorion and Sweeney (1996), Papell (1997), Papell and Theodoridis (1998), and O'Connell (1998) use panel methods and provide mixed results regarding long-run PPP.

Although long-run PPP has been investigated in a large number of recent studies, these typically require the researcher to take a stance on a common order of integration for the individual price and exchange rate series. As a result, most of the literature ignores a recent important contribution to this topic by Ng and Perron (1997) who show that we should be very wary of estimation and inference in nearly unbalanced nearly cointegrated systems. In this paper we use the recent Pesaran et al. (1999) bounds test approach to the analysis of the theory of long-run PPP. This is a particularly relevant methodology as it does not require that we take a stand on the time series properties of the data. Therefore we are able to test for the existence of a long-run relationship without having to assume that the exchange rate and price series are $I(0)$, $I(1)$, or even integrated of the same order. In doing so, we test the absolute and relative PPP hypotheses during the recent flexible exchange rate period for 21 OECD countries.

The paper consists of three sections. Section 2 provides a brief discussion of the Pesaran et al. (1999) bounds tests for long-run level relationships. Section 3 presents empirical results for absolute and relative PPP. The last section summarizes and concludes the paper.

2. A bounds testing approach

This section summarizes the autoregressive distributed lag, bounds test approach to testing for the existence of a single long-run relationship between the natural logarithm of the nominal exchange rate, s_t, and $\mathbf{x}_t$, where $\mathbf{x}_t$ is either the scalar time series $p_t - p_t^*$, or the vector time series $\{p_t, p_t^*\}$. In each case p_t is the natural logarithm of the domestic price level and p_t^* is the natural logarithm of the foreign price level. For a more general and comprehensive description of the methodology, see Pesaran et al. (1999).

We begin with an unrestricted vector autoregression

$$\mathbf{z}_t = \boldsymbol{\mu} + \boldsymbol{\delta} t + \sum_{j=1}^{p} \boldsymbol{\phi}_j \mathbf{z}_{t-j} + \boldsymbol{\varepsilon}_t, \tag{1}$$

where $\mathbf{z}_t = [s_t \ \mathbf{x}_t]'$, $\boldsymbol{\mu}$ is a vector of constant terms, $\boldsymbol{\mu} = [\mu_s \ \boldsymbol{\mu}_{\mathbf{x}}]'$, t is a linear time trend, $\boldsymbol{\delta} = [\delta_s \ \boldsymbol{\delta}_{\mathbf{x}}]'$ and $\boldsymbol{\phi}_j$ is a matrix of VAR parameters for lag j. As noted earlier, the two series s_t and $\mathbf{x}_t$ can be either $I(0)$ or $I(1)$. In the case when $\mathbf{x}_t$ is a vector time series the two price series can also be of different orders of integration. When $\mathbf{x}_t = p_t - p_t^*$, Eq. (1) describes a bivariate VAR and when $\mathbf{x}_t = \{p_t, p_t^*\}$ it describes a trivariate VAR.

The vector of error terms $\boldsymbol{\varepsilon}_t = [\varepsilon_{s,t}\ \boldsymbol{\varepsilon}_{\mathbf{x},t}]' \sim \mathbb{N}(\mathbf{0}, \Omega)$ where Ω is positive definite and given by

$$\Omega = \begin{bmatrix} \omega_{ss} & \boldsymbol{\omega}_{s\mathbf{x}} \\ \boldsymbol{\omega}_{s\mathbf{x}} & \boldsymbol{\omega}_{\mathbf{xx}} \end{bmatrix}.$$

Given this, $\varepsilon_{s,t}$ can be expressed in terms of $\boldsymbol{\varepsilon}_{\mathbf{x},t}$ as

$$\varepsilon_{s,t} = \boldsymbol{\omega}\varepsilon_{\mathbf{x},t} + u_t, \tag{2}$$

where $\boldsymbol{\omega} = \boldsymbol{\omega}_{s\mathbf{x}}/\boldsymbol{\omega}_{\mathbf{xx}}$ and $u_t \sim \mathbb{N}(0, \omega_{ss})$.

Manipulation of Eq. (1) allows us to write it as a vector error correction model, as follows:

$$\Delta\mathbf{z}_t = \boldsymbol{\mu} + \boldsymbol{\delta}t + \boldsymbol{\lambda}\mathbf{z}_{t-1} + \sum_{j=1}^{p-1}\boldsymbol{\gamma}_j\Delta\mathbf{z}_{t-j} + \boldsymbol{\varepsilon}_t, \tag{3}$$

where $\Delta = 1 - L$, and

$$\boldsymbol{\gamma}_j = \begin{bmatrix} \gamma_{ss,j} & \boldsymbol{\gamma}_{s\mathbf{x},j} \\ \boldsymbol{\gamma}_{s\mathbf{x},j} & \boldsymbol{\gamma}_{\mathbf{xx},j} \end{bmatrix} = -\sum_{k=j+1}^{p}\boldsymbol{\phi}_k.$$

Here $\boldsymbol{\lambda}$ is the long-run multiplier matrix and is given by

$$\boldsymbol{\lambda} = \begin{bmatrix} \lambda_{ss} & \boldsymbol{\lambda}_{s\mathbf{x}} \\ \boldsymbol{\lambda}_{\mathbf{x}s} & \boldsymbol{\lambda}_{\mathbf{xx}} \end{bmatrix} = -\left(\mathbf{I} - \sum_{j=1}^{p}\boldsymbol{\phi}_j\right),$$

where $\mathbf{I}$ is an identity matrix. The diagonal elements of this matrix are left unrestricted. This allows for the possibility that each of the series can be either $I(0)$ or $I(1)$ – for example, $\lambda_{ss} = 0$ implies that the nominal exchange rate is $I(1)$ and $\lambda_{ss} < 0$ implies that it is $I(0)$.

This procedure allows for the testing of the existence of a maximum of one long-run relationship that includes both s_t and $\mathbf{x}_t$. This implies that only one of $\boldsymbol{\lambda}_{\mathbf{x}s}$ and $\boldsymbol{\lambda}_{s\mathbf{x}}$ can be nonzero. As our interest is on the long-run effect of the level of the price series on the exchange rate, we impose the restriction $\boldsymbol{\lambda}_{\mathbf{x}s} = 0$. This implies that the nominal exchange rate has no long-run impact on the domestic and foreign price levels or that the domestic and foreign price level series are *long-run forcing* for the exchange rate, in the terminology of Pesaran et al. (1999). Note that this does not preclude the exchange rate being Granger causal for the domestic and foreign price levels in the short-run. These effects are captured through the short-run response coefficients described by the matrices $\boldsymbol{\phi}_1$ to $\boldsymbol{\phi}_p$.

Under the assumption $\boldsymbol{\lambda}_{\mathbf{x}s} = 0$, and using (2), the equation for the nominal exchange rate from (3) can be written as

$$\Delta s_t = \alpha_0 + \alpha_1 t + \varphi s_{t-1} + \boldsymbol{\psi}\mathbf{x}_{t-1} + \sum_{j=1}^{p-1} \beta_{s,j}\Delta s_{t-j} + \sum_{j=1}^{\mathbf{q}-1} \boldsymbol{\beta}_{\mathbf{x},j}\Delta \mathbf{x}_{t-j} + \boldsymbol{\omega}\Delta\mathbf{x}_t + u_t, \tag{4}$$

where $\alpha_0 = \mu_s - \boldsymbol{\omega}'\boldsymbol{\mu}_{\mathbf{x}}$, $\alpha_1 = \delta_s + \boldsymbol{\omega}'\boldsymbol{\delta}_{\mathbf{x}}$, $\varphi = \lambda_{ss}$, $\boldsymbol{\psi} = \boldsymbol{\lambda}_{s\mathbf{x}} - \boldsymbol{\omega}'\boldsymbol{\lambda}_{\mathbf{xx}}$, $\beta_{s,j} = \gamma_{ss,j} - \boldsymbol{\omega}'\boldsymbol{\gamma}_{\mathbf{x}s,j}$ and $\boldsymbol{\beta}_{\mathbf{x},j} = \boldsymbol{\gamma}_{s\mathbf{x},j} - \boldsymbol{\omega}'\boldsymbol{\gamma}_{\mathbf{xx},j}$. This can also be interpreted as an autoregressive distributed lag [ARDL($p, \mathbf{q}$)] model. We estimate Eq. (4) by ordinary least squares and test the absence of a long-run relationship between s_t and $\mathbf{x}_t$, by calculating the F statistic for the null hypothesis of $\varphi = \boldsymbol{\psi} = 0$. Under the alternative of interest, $\varphi \neq 0$ and $\boldsymbol{\psi} \neq 0$, there is a stable long-run relationship between s and $\mathbf{x}$, which is described by

$$s_t = \theta_0 + \theta_1 t + \boldsymbol{\theta}_2\mathbf{x}_t + v_t,$$

where $\theta_0 = -\alpha_0/\varphi$, $\theta_1 = -a_1/\varphi$, $\boldsymbol{\theta}_2 = \boldsymbol{\delta}/\varphi$ and v_t is a mean zero stationary process.

The distribution of the test statistic under the null depends on the order of integration of s_t and $\mathbf{x}_t$. For example, in the bivariate (trivariate) case where all variables are $I(0)$, and the regression includes an unrestricted intercept and trend, the appropriate 95% asymptotic critical value is 6.56 (4.87). When all variables are $I(1)$ this critical value is 7.30 (5.85). For cases in which one series is $I(0)$ and the other is $I(1)$, the 95% asymptotic critical value falls in-between these two bounds – see Pesaran et al. (1999, Table C1.v).

The discussion so far pertains to a test of absolute purchasing power parity. For a test of relative PPP, in Eq. (4) we replace s_t with Δs_t, p_t with $\pi_t (= \Delta p_t)$, and p_t^* with $\pi_t^* (= \Delta p_t^*)$. That is, we use the percentage rate of change in the nominal exchange rate and the domestic and foreign inflation rates.

3. Empirical evidence

We use quarterly data over the recent floating exchange rate period, from 1973:1 to 1998:4, for 21 OECD countries – Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and the United States. The data are nominal, end-of-period exchange rates and Consumer Price Indexes from the International Financial Statistics of the International Monetary Fund. We exclude Iceland, because of gaps in its CPI series, and Luxemburg because of its currency union with Belgium. In conducting our tests, we use the United States dollar, the German mark, and the Japanese yen as the base currencies, thereby investigating a total of 60 bivariate and trivariate relations.

One preliminary matter also has to be dealt with before we can proceed to perform Pesaran et al. (1999) bounds tests for long-run absolute and relative PPP. It concerns the lengths of lags p and $\mathbf{q}$ in Eq. (4). In practice, there is no reason why p and $\mathbf{q}$ in (4) should have the same value, and we allow for this possibility. In particular, we consider values from 1 to 8 for each of p and $\mathbf{q}$ in (4), and we report results for those specifications that minimize the Akaike information criterion (AIC) value. [2] Of course, the AIC is only one of a number of possible statistical criteria that could be used to select the 'optimal' lag length – for a discussion of some of these and references to others, see Priestley (1981, pp. 370–376). To investigate the robustness of our results to alternative model selection criteria, we also report results based on the Schwartz (1978) Bayesian information criterion (BIC).

We follow the bounds test approach suggested by Pesaran et al. (1999) and reject the null hypothesis, in favor of the alternative that there exists a long-run relationship between the nominal exchange rate and the domestic and foreign price levels, at a particular significance level when our sample test statistic is above the associated upper critical value. The null hypothesis is rejected regardless of whether the series are $I(0)$ or $I(1)$. We accept the null when our sample test statistic is below the relevant lower critical value. When the sample test statistic falls in-between these two bounds we interpret the result as being inconclusive at this particular significance level.

3.1. Evidence from bivariate relations

Tables 1 and 2 contain the results of the bounds tests for absolute (Table 1) and relative (Table 2) PPP, based on bivariate relationships. For each of the hypotheses, we present the F-statistic for the null of no long-run relationship between the nominal exchange rate, s_t, and the relative price, $p_t - p_t^*$, based on the optimal AIC specification. To deal with anomalies that arise regarding the power of the test when the form of the data-generating process is unknown, tests are conducted against two alternatives, one consistent with fluctuations around a constant mean, the other with stationary fluctuations around a deterministic trend. Looking at the data, however, it appears that the bilateral rates examined here are invariant over the sample period and we shall therefore focus our discussion on the 'without trend' version of the test, although we also report results for the 'with trend' version of the test.

[2] In the bivariate case where $\mathbf{x}_t = p_t - p_t^*$, $\mathbf{q}$ is a scalar. In this case, for each bivariate relationship we run 64 regressions and choose the specification that minimizes the AIC. In the trivariate case where $\mathbf{x}_t = \{p_t, p_t^*\}$, $\mathbf{q} = \{q_1, q_2\}$, where q_1 is the number of lags of the domestic price level, p_t, and q_2 is the number of lags of the foreign price level, p_t^*. In this case, for each trivariate relationship we run 512 regressions and choose the specification that minimizes the AIC.

Table 1
Bivariate tests of absolute PPP based on those specifications that minimize the AIC[a]

Country	Without trend						With trend					
	US		DM		Yen		US		DM		Yen	
Australia	[1,1]	0.87	[1,1]	2.89	[2,1]	2.29	[1,1]	3.69	[4,1]	4.81	[2,1]	2.34
Austria	[5,5]	2.19	[2,1]	3.56	[6,4]	4.54	[5,1]	5.81	[2,1]	3.84	[6,1]	2.87
Belgium	[4,5]	1.91	[2,1]	1.67	[6,3]	2.95	[3,2]	11.72	[2,1]	0.67	[6,3]	2.45
Canada	[4,1]	1.02	[8,1]	3.05	[2,1]	1.59	[4,1]	3.12	[8,1]	4.55	[5,1]	4.92
Denmark	[4,1]	2.21	[1,1]	4.67	[6,1]	4.35	[4,1]	2.04	[1,1]	2.17	[6,1]	3.18
Finland	[8,1]	3.98	[4,8]	9.72	[6,2]	6.43	[8,1]	5.21	[6,8]	17.66	[2,1]	4.44
France	[5,3]	8.91	[4,5]	12.8	[6,1]	6.90	[1,3]	7.50	[4,4]	11.94	[6,1]	5.62
Germany	[5,1]	2.90	–	–	[7,3]	1.61	[5,2]	5.02	–	–	[2,1]	4.75
Greece	[5,2]	3.69	[2,5]	2.63	[6,2]	2.61	[5,2]	3.67	[2,5]	3.75	[6,2]	2.72
Ireland	[6,7]	7.01	[3,5]	8.02	[2,1]	7.56	[6,7]	6.21	[7,1]	7.24	[2,1]	6.93
Italy	[5,7]	7.61	[1,4]	8.08	[2,1]	4.85	[2,7]	6.94	[1,4]	2.13	[8,1]	5.85
Japan	[4,1]	1.16	[7,3]	1.61	–	–	[5,1]	3.84	[2,1]	4.75	–	–
Netherlands	[5,1]	3.07	[5,2]	8.28	[6,1]	1.14	[5,1]	4.66	[8,4]	16.06	[6,1]	3.08
New Zealand	[1,5]	3.34	[1,1]	5.10	[1,1]	3.98	[1,1]	1.90	[4,1]	5.23	[1,1]	1.80
Norway	[8,1]	2.81	[1,1]	2.63	[2,1]	4.61	[8,3]	5.70	[6,1]	8.50	[2,2]	5.44
Portugal	[4,2]	3.71	[5,4]	8.70	[3,5]	6.21	[3,2]	4.45	[5,4]	8.16	[3,5]	4.86
Spain	[4,1]	2.74	[1,1]	2.70	[3,1]	5.91	[4,1]	2.72	[1,1]	3.45	[3,1]	5.62
Sweden	[4,1]	2.46	[6,8]	8.54	[2,1]	5.15	[4,1]	6.06	[6,8]	8.64	[2,1]	4.99
Switzerland	[5,1]	3.15	[1,1]	4.64	[2,8]	6.06	[5,1]	5.95	[1,1]	10.62	[2,1]	4.95
United Kingdom	[8,1]	5.38	[1,1]	3.78	[2,2]	6.10	[8,1]	5.30	[1,1]	2.73	[2,2]	4.37
United States	–	–	[5,1]	2.90	[4,1]	1.16	–	–	[5,2]	5.02	[5,1]	3.84

[a] Numbers in brackets indicate the optimal lag structure. For the case without trend, the 95% asymptotic critical value is 5.73 when all series are $I(1)$, 4.94 when they are $I(0)$, and falls in the interval [4.94, 5.73] when one series is $I(0)$ and one is $I(1)$ – see Pesaran et al. (1999, Table C1.iii). For the case with trend, the 95% asymptotic critical value is 7.30 when all series are $I(1)$, 6.56 when they are $I(0)$, and falls in the interval [6.56, 7.30] when one series is $I(0)$ and one is $I(1)$ – see Pesaran et al. (1999, Table C1.v).

Table 2
Bivariate tests of relative PPP based on those specifications that minimize the AIC[a]

Country	Without trend						With trend					
	US		DM		Yen		US		DM		Yen	
Australia	[1,1]	52.2	[1,1]	46.2	[1,1]	35.3	[1,4]	54.5	[1,1]	4.58	[1,1]	35.4
Austria	[3,4]	13.9	[1,1]	93.5	[6,8]	18.0	[3,4]	13.7	[1,1]	92.5	[6,8]	19.2
Belgium	[3,4]	14.0	[1,1]	32.5	[5,2]	19.1	[3,2]	14.1	[1,1]	33.4	[5,2]	19.4
Canada	[3,2]	9.42	[7,1]	6.16	[1,1]	30.4	[3,1]	9.24	[7,1]	6.59	[1,1]	30.6
Denmark	[3,1]	10.4	[1,1]	51.8	[5,3]	17.3	[5,1]	10.6	[1,1]	56.6	[5,3]	17.8
Finland	[5,1]	10.2	[1,8]	52.7	[1,2]	24.8	[5,1]	10.0	[1,8]	52.9	[5,1]	15.0
France	[1,1]	40.6	[6,1]	16.7	[5,1]	17.7	[2,1]	28.7	[6,1]	16.6	[5,1]	18.2
Germany	[4,2]	7.12	–	–	[6,1]	18.1	[4,2]	7.23	–	–	[6,2]	19.4
Greece	[4,1]	7.03	[1,4]	66.1	[5,1]	18.1	[4,1]	7.20	[1,4]	66.1	[5,1]	19.0
Ireland	[5,1]	11.9	[2,1]	17.1	[5,4]	13.5	[5,1]	11.9	[2,1]	17.1	[5,1]	15.7
Italy	[1,1]	35.4	[1,7]	48.2	[1,1]	25.0	[1,1]	35.0	[1,3]	61.8	[5,1]	15.8
Japan	[3,1]	11.2	[6,1]	18.1	–	–	[3,1]	11.1	[6,2]	19.4	–	–
Netherlands	[5,4]	9.90	[4,6]	36.6	[5,1]	20.0	[5,4]	9.70	[4,1]	39.26	[6,8]	18.3
New Zealand	[4,1]	11.2	[3,1]	12.8	[1,1]	42.4	[1,4]	42.6	[4,1]	12.7	[1,1]	46.9
Norway	[2,1]	33.3	[1,1]	38.2	[8,4]	5.21	[2,1]	32.9	[1,1]	37.8	[8,4]	5.32
Portugal	[3,2]	11.2	[7,4]	7.46	[1,4]	23.4	[1,3]	38.2	[7,3]	9.48	[1,4]	25.1
Spain	[1,4]	34.4	[1,1]	39.4	[5,1]	14.6	[1,4]	35.0	[1,1]	39.0	[5,1]	14.6
Sweden	[1,4]	9.66	[1,8]	44.4	[1,1]	24.8	[3,2]	9.61	[2,8]	31.6	[1,1]	24.5
Switzerland	[1,2]	41.1	[2,1]	32.9	[1,1]	37.7	[1,2]	40.8	[2,1]	33.42	[1,1]	37.1
United Kingdom	[6,1]	6.83	[1,1]	38.3	[1,1]	23.6	[6,1]	6.88	[1,1]	39.3	[2,1]	22.2
United States	–	–	[4,2]	7.12	[3,1]	11.2	–	–	[4,2]	7.23	[3,1]	11.1

[a] Numbers in brackets indicate the optimal lag structure. For the case without trend, the 95% asymptotic critical value is 5.73 when all series are $I(1)$, 4.94 when they are $I(0)$, and falls in the interval [4.94, 5.73] when one series is $I(0)$ and one is $I(1)$ – see Pesaran et al. (1999, Table C1.iii). For the case with trend, the 95% asymptotic critical value is 7.30 when all series are $I(1)$, 6.56 when they are $I(0)$, and falls in the interval [6.56, 7.30] when one series is $I(0)$ and one is $I(1)$ – see Pesaran et al. (1999, Table C1.v).

Generally speaking, for the without trend case the results provide very little empirical evidence consistent with absolute PPP when the US dollar is the base currency – we reject the null of no long-run relationship between the nominal exchange rate and the relative price only in the case of France, Ireland, and Italy, regardless of whether the underlying series are $I(0)$, $I(1)$, or mutually cointegrated. The results in Table 2, however, indicate that relative PPP is accepted with all currencies.

It has been argued that PPP could work better in groups of countries in close geographical proximity, because of lower transaction costs – see, for example, Mark (1990) and Papell (1997). As we can see from Table 1, when the DM is used as the base currency, the null hypothesis of no long-run relationship between the nominal exchange rate and the relative price is rejected for seven out of the 21 countries – Finland, France, Ireland, Italy, the Netherlands, Portugal, and Sweden. This provides evidence for regional effects in the analysis of PPP, since, the currencies of these countries have been following the German mark over the last 25 years and the volatility of exchange rates (both nominal and real) has been lower than relative to the US dollar. Regarding relative PPP, the results (in Table 2) are again overwhelmingly in favor of the hypothesis, for all currencies.

Finally, Tables 1 and 2 show results for the case where the Japanese yen is the base currency. In this case, there are also seven countries – Finland, France, Ireland, Portugal, Spain, Switzerland, and the United Kingdom – for which the null hypothesis of no long-run relationship between the nominal exchange rate and the relative price can be rejected, irrespective of the univariate time series properties of the variables. There is again, however, overwhelming evidence in favor of relative PPP, as can be seen in Table 2.

As we argued earlier, a basic statistical issue is the appropriate representation of the lag structure in Eq. (4). To investigate the robustness of our results to alternative model selection procedures, in Appendix A (see Tables 6 and 7) we report results (in the same fashion as those in Tables 1 and 2) based on the BIC. [3] Clearly, for the without trend version of the test in Appendix A (see Table 6), there is no evidence consistent with absolute PPP when the US dollar is used as the base currency. When the DM is used as the base currency, there is now evidence consistent with PPP only for four countries – Finland, Italy, the Netherlands, and Portugal. Finally, when the yen is the base currency, the null hypothesis of no long-run relationship is rejected for only France and Ireland. Of course, the evidence in Appendix A (see Table 7) is again overwhelmingly in favor of the hypothesis of relative PPP.

[3] In general, the BIC selects shorter lag lengths than the AIC. It should be noted, however, that the AIC is our preferred criterion due to the importance of serially uncorrelated errors for this bounds test – see Pesaran et al. (1999) for more details.

Overall, based on bivariate relationships, the evidence of absolute PPP is stronger when the Japanese yen and the German mark are used as the base currencies, rather than the US dollar. Papell (1997), Papell and Theodoridis (1998), Koedijk et al. (1998), and Boyd and Smith (1999) provide some explanations for the weakness observed when the US dollar is used as the base currency. These include references to the 1980–1987 period during which the dollar first strongly depreciated and afterwards strongly appreciated, as well as the longer swings in the US real exchange rate.

3.2. Evidence from trivariate relations

So far, we have tested PPP as a long-run relationship in terms of the bivariate system, $[s_t, p_t - p_t^*]$. We can also test for (absolute and relative) PPP, using the Pesaran et al. (1999) methodology, in terms of the trivariate system, $[s_t, p_t, p_t^*]$. The results of these tests are presented in Tables 3 and 4, and Appendix A (see Tables 8 and 9), in the same fashion as those for the bivariate relationships in Tables 1 and 2, and Appendix A (see Tables 6 and 7).

Although there is some evidence in favor of long-run absolute purchasing power parity, these results are difficult to interpret. Recall that the methodology of Pesaran et al. (1999) allows us to test for the existence of a long-run relationship when there is uncertainty over whether the individual series are $I(0)$ or $I(1)$, but not if one or more of the series is integrated of orders two or greater. In the bivariate relationships, it seems unlikely for either the relative price series $(p_t - p_t^*)$ or the inflation rate series, π_t and π_t^*, to be $I(2)$. In the trivariate relationships, however, it is likely that some price level series grow at an increasing rate, and thus are $I(2)$.

In order to get an idea of which countries' price level series might be $I(2)$, when measured in natural logarithms, we used the augmented Dickey–Fuller test and the Elliot et al. (1996) modification to the ADF test (known as the DF-GLS test), which has substantially improved power relative to the standard ADF test when an unknown mean or trend is present. Using these tests we fail to uncover any evidence suggesting a rejection of the null of $I(2)$ against the alternative that the series is integrated of order one, or less, for Austria, Greece and the Netherlands. For this reason, while we report the results from the trivariate regressions that pertain to absolute PPP, we advise the reader to treat the results for these countries with caution.

However, as with our evidence from the bivariate regressions, the results in these tables are consistent with a long-run relationship between the rate of change in the nominal exchange rate and the domestic and foreign inflation rates, irrespective of whether the regressors are $I(0)$ or $I(1)$. Moreover, this evidence is robust across the three countries used as the 'home country' in the trivariate relations.

Table 3
Trivariate tests of absolute PPP based on those specifications that minimize the AIC[a]

Country	Without trend						With trend					
	US		DM		Yen		US		DM		Yen	
Australia	[1,2,2]	6.77	[5,7,1]	5.45	[2,1,1]	1.65	[1,6,2]	7.44	[7,7,1]	8.46	[2,1,1]	1.73
Austria	[1,4,2]	4.20	[2,3,1]	4.95	[6,1,5]	3.28	[1,4,2]	1.75	[4,3,1]	6.31	[6,3,1]	6.24
Belgium	[3,4,2]	4.76	[2,6,1]	1.41	[4,7,3]	7.48	[5,6,8]	4.51	[1,4,1]	3.76	[4,7,3]	9.59
Canada	[4,3,1]	3.57	[1,8,1]	3.69	[2,8,1]	5.58	[4,3,1]	4.57	[1,8,1]	0.82	[2,8,1]	4.46
Denmark	[4,1,1]	1.18	[1,1,3]	1.77	[6,1,1]	2.86	[4,1,2]	4.49	[3,1,3]	6.67	[6,1,1]	3.36
Finland	[8,1,1]	4.36	[4,6,7]	11.7	[2,1,1]	3.43	[8,1,7]	8.52	[4,6,6]	20.1	[2,1,1]	3.41
France	[1,1,5]	4.40	[4,1,2]	10.3	[6,1,3]	4.98	[1,1,2]	3.61	[6,5,2]	13.6	[6,1,1]	4.58
Germany	[5,1,5]	2.70	–	–	[6,1,5]	4.40	[5,1,5]	3.10	–	–	[6,1,5]	4.61
Greece	[5,1,1]	4.08	[1,5,2]	3.68	[6,1,3]	2.21	[5,1,1]	4.61	[1,5,2]	5.79	[6,1,3]	3.91
Ireland	[6,5,1]	3.52	[7,5,2]	7.18	[2,1,1]	4.79	[6,5,2]	3.32	[7,5,2]	6.98	[2,1,1]	4.65
Italy	[1,6,2]	5.18	[1,4,4]	4.44	[2,3,1]	4.48	[1,1,2]	5.76	[1,5,4]	3.09	[8,1,3]	4.87
Japan	[1,1,1]	2.37	[6,5,1]	4.40	–	–	[1,1,1]	2.85	[6,5,1]	4.61	–	–
Netherlands	[6,4,5]	2.21	[8,4,1]	13.4	[6,1,7]	6.03	[6,4,1]	2.35	[5,4,1]	10.6	[6,1,7]	6.08
New Zealand	[1,2,5]	1.16	[1,1,1]	3.24	[1,1,1]	2.50	[1,5,2]	6.97	[1,1,1]	3.75	[1,1,1]	1.68
Norway	[1,1,2]	4.05	[1,1,1]	3.45	[2,1,2]	3.43	[1,1,2]	5.46	[1,1,1]	2.55	[2,1,2]	3.58
Portugal	[1,2,2]	7.27	[5,1,1]	5.40	[3,5,3]	4.46	[6,4,8]	9.22	[5,4,2]	9.33	[3,5,3]	5.28
Spain	[1,3,1]	5.60	[1,3,2]	6.34	[3,1,1]	3.35	[1,3,1]	7.26	[1,1,2]	7.00	[3,1,1]	3.15
Sweden	[4,1,1]	5.52	[7,8,3]	7.82	[2,1,1]	3.59	[4,1,1]	4.98	[7,8,3]	7.84	[2,1,1]	3.50
Switzerland	[5,1,2]	3.54	[1,2,1]	10.2	[1,1,1]	3.46	[5,1,2]	3.52	[1,2,1]	10.3	[1,3,1]	5.83
United Kingdom	[8,1,2]	6.45	[1,1,1]	2.96	[2,2,1]	3.30	[8,1,4]	9.99	[1,1,1]	2.06	[2,2,1]	2.84
United States	–	–	[5,5,1]	2.70	[1,1,1]	2.37	–	–	[5,5,1]	3.10	[1,1,1]	2.85

[a] Numbers in brackets indicate the optimal lag structure. For the case without trend, the 95% asymptotic critical value is 4.85 when all series are $I(1)$, 3.79 when they are $I(0)$, and falls in the interval [3.79, 4.85] when one series is $I(0)$ and one is $I(1)$ – see Pesaran et al. (1999, Table C1.iii)). For the case with trend, the 95% asymptotic critical value is 5.85 when all series are $I(1)$, 4.87 when they are $I(0)$, and falls in the interval [4.87, 5.85] when one series is $I(0)$ and one is $I(1)$ – see Pesaran et al. (1999, Table C1.v).

Table 4
Trivariate tests of relative PPP based on those specifications that minimize the AIC[a]

Country	Without trend						With trend					
	US		DM		Yen		US		DM		Yen	
Australia	[1,1,2]	35.7	[3,1,1]	7.34	[1,1,1]	22.9	[1,1,2]	36.7	[3,1,1]	7.28	[1,1,1]	22.6
Austria	[3,3,4]	8.86	[1,7,2]	69.1	[5,3,2]	15.3	[6,7,4]	9.15	[1,7,2]	68.8	[5,3,2]	15.1
Belgium	[3,3,4]	11.0	[1,3,1]	25.4	[6,6,2]	9.69	[2,3,4]	25.8	[1,3,1]	24.5	[6,6,2]	9.88
Canada	[3,2,1]	5.90	[7,2,1]	3.50	[1,1,1]	19.9	[3,2,1]	6.07	[1,8,1]	27.7	[1,3,1]	20.9
Denmark	[3,1,4]	9.23	[1,1,2]	38.9	[5,3,1]	12.0	[3,1,4]	9.74	[1,1,2]	39.3	[5,3,1]	11.9
Finland	[5,1,4]	8.08	[2,8,8]	11.7	[1,2,1]	18.3	[5,1,4]	8.12	[2,8,8]	12.1	[5,1,1]	9.81
France	[1,1,4]	29.4	[6,1,1]	10.9	[5,1,1]	11.9	[1,1,4]	32.2	[6,1,1]	11.1	[5,1,1]	11.8
Germany	[6,1,4]	7.71	–	–	[6,1,1]	12.6	[6,1,4]	9.04	–	–	[6,1,2]	12.5
Greece	[4,1,1]	5.40	[1,4,1]	41.2	[5,1,1]	12.3	[4,1,1]	5.21	[1,4,1]	41.7	[5,1,2]	11.8
Ireland	[6,1,4]	11.0	[2,6,1]	11.5	[5,4,1]	10.5	[6,4,4]	11.6	[2,1,1]	11.2	[5,1,2]	9.95
Italy	[1,2,4]	25.1	[1,7,3]	35.1	[5,4,2]	10.4	[1,1,4]	24.6	[1,3,3]	38.7	[5,4,2]	10.3
Japan	[3,1,1]	7.22	[6,1,1]	12.6	–	–	[1,1,1]	21.3	[6,2,1]	12.5	–	–
Netherlands	[5,4,4]	7.64	[4,5,1]	26.1	[5,3,1]	13.3	[5,3,4]	9.27	[6,1,1]	18.1	[5,4,1]	13.8
New Zealand	[1,1,4]	29.3	[3,1,1]	8.35	[1,1,1]	29.3	[1,4,4]	30.3	[3,1,1]	8.33	[1,1,1]	30.5
Norway	[7,1,4]	5.06	[1,2,1]	25.7	[1,1,1]	18.9	[7,1,4]	5.51	[1,1,1]	27.0	[1,1,1]	18.8
Portugal	[3,2,4]	8.50	[7,4,1]	5.70	[2,4,1]	7.43	[1,1,4]	29.4	[7,4,1]	6.99	[2,4,1]	7.34
Spain	[1,1,4]	24.8	[1,1,2]	27.8	[5,1,1]	9.82	[1,2,4]	24.2	[1,1,3]	27.8	[5,1,1]	9.82
Sweden	[3,2,1]	5.97	[1,8,2]	28.8	[1,1,1]	16.2	[3,1,1]	7.05	[1,8,2]	28.2	[1,1,1]	16.1
Switzerland	[1,1,2]	26.9	[1,1,1]	47.1	[1,1,1]	24.9	[1,1,2]	27.5	[1,1,1]	47.1	[1,1,1]	24.6
United Kingdom	[5,1,8]	12.4	[1,1,2]	25.0	[2,1,5]	17.3	[7,1,8]	6.81	[1,1,2]	25.5	[4,1,5]	14.0
United States	–	–	[6,4,1]	7.71	[3,1,1]	7.22	–	–	[6,4,1]	9.04	[1,1,1]	21.3

[a] Numbers in brackets indicate the optimal lag structure. For the case without trend, the 95% asymptotic critical value is 4.85 when all series are $I(1)$, 3.79 when they are $I(0)$, and falls in the interval [3.79, 4.85] when one series is $I(0)$ and one is $I(1)$ – see Pesaran et al. (1999, Table C1.iii). For the case with trend, the 95% asymptotic critical value is 5.85 when all series are $I(1)$, 4.87 when they are $I(0)$, and falls in the interval [4.87, 5.85] when one series is $I(0)$ and one is $I(1)$ – see Pesaran et al. (1999, Table C1.v).

3.3. Error-correction terms

An important feature of cointegrated variables is that their short-run dynamics are influenced by the deviation from long-run equilibrium. In other words, if the system is to return to the long-run equilibrium, the movements of at least some of the variables must be influenced by the magnitude of the deviation from the long-run relationship. If, for example, the gap between the cointegrating nominal exchange rate, s_t, and the relative price, $p_t - p_t^*$, is large relative to the long-run relationship, the gap must ultimately close by adjustments in s_t, $p_t - p_t^*$, or both.

To see the short-run dynamics implied by our bounds testing approach, we report in Table 5 the estimated error-correction coefficients for those bivariate and trivariate relationships for which the null hypothesis of no long-run relationship is rejected. These estimates are based on the specifications in which the trend is excluded and the lag order is selected using the AIC. [4] For both the absolute and relative PPP relationships there is typically little difference in the estimated error correction term across the bivariate and trivariate cases. The error correction terms that refer to absolute PPP are typically in the range 0.15–0.40, implying a moderate speed of convergence to long-run equilibrium. The error correction terms that pertain to relative PPP imply a much higher speed of convergence – they typically fall between 0.80 and 1.10. [5]

4. Conclusion

The theory of PPP has been investigated in a large number of recent studies, using recent advances in the field of applied econometrics. Most of the literature, however, ignores a recent important contribution to this topic by Ng and Perron (1997) who show that we should be very wary of estimation and inference in nearly unbalanced nearly cointegrated systems. To circumvent the Ng and Perron (1997) critique issues, in this paper we have used the Pesaran et al. (1999) bounds test approach to test the existence of long-run absolute and relative PPP. This is a particularly useful methodology when it is not known with certainty whether the underlying variables are trend- or first-difference stationary.

[4] Estimates from other specifications yield similar results and are available from the authors on request.

[5] The standard errors on these error correction coefficients do not have the standard interpretation. However, they do suggest statistical significance of the error correction terms, since in general they imply t-statistics in the range 3–4 for the absolute PPP regression and in the range 5–8 for the relative PPP regression.

Table 5
Estimated error-correction coefficients based on (without trend) bivariate and trivariate specifications that minimize the AIC[a]

Country	Absolute PPP						Relative PPP					
	US		DM		Yen		US		DM		Yen	
	Biv.	Triv.	Biv.	Triv.	Biv.	Triv.	Biv.	Triv.	Biv.	Triv.	Biv.	Triv.
Australia		−0.16		−0.22			−1.07	−1.05	−1.00	−0.88	−0.89	−0.88
Austria		−0.08*		−0.27			−0.91	−1.12	−1.34	−1.42	−1.50	−1.39
Belgium		−0.01*				−0.31	−0.94	−0.95	−0.83	−0.88	−1.21	−1.23
Canada						−0.15	−0.76	−0.74	−0.78	−0.79	−0.81	−0.81
Denmark							−0.75	−0.86	−1.09	−1.12	−1.18	−1.16
Finland		−0.14*	−0.32	−0.37	−0.14		−0.77	−0.82	−1.04	−0.91	−0.73	−0.76
France	−0.26	0.13*	−0.29	−0.35	−0.24	−0.29	−0.93	−0.97	−1.15	−1.15	−1.15	−1.13
Germany			–	–		−0.24*	−0.64	−1.05	–	–	−1.45	−1.51
Greece		−0.14*					−0.78	−0.77	−1.21	−1.22	−1.12	−1.10
Ireland	−0.24		−0.18	−0.28	−0.15	−0.17*	−1.04	−1.21	−0.85	−0.85	−1.00	−1.03
Italy	−0.21	−0.12	−0.10	−0.15*	−0.13*	−0.15*	−0.87	−0.90	−1.12	−1.13	−0.74	−1.01
Japan				−0.24*	–	–	−0.86	−0.75	−1.45	−1.51	–	–
Netherlands			−0.16	−0.57		−0.24	−0.89	−0.89	−2.24	−2.13	−1.17	−1.18
New Zealand			−0.19*				−0.90	−0.96	−1.04	−1.05	−0.99	−1.00
Norway		−0.14*					−0.99	−1.02	−0.91	−0.92	−0.94*	−0.83
Portugal		−0.09	−0.16	−0.17	−0.15	−0.17*	−0.92	−0.85	−0.85	−0.91	−0.72	−0.61
Spain		−0.03		−0.23	−0.16		−0.82	−0.88	−0.95	−0.94	−0.98	−0.92
Sweden		−0.14	−0.29	−0.44	−0.15*		−0.84	−0.67	−1.00	−0.99	−0.74	−0.74
Switzerland		−0.23		−0.39	−0.19		−0.95	−0.97	−1.23	−1.10	−0.94	−0.95
United Kingdom	−0.16*				−0.11		−0.87	−1.43	−0.91	−0.90	−0.73	−1.01
United States	–	–					–	–	−0.64	−1.05	−0.75	−0.75

[a] Error-correction terms are reported for cases in which the null hypothesis of no long-run relationship is rejected. An asterisk indicates that the test statistic falls between the two bounds. Otherwise, the null is rejected regardless of whether the series are $I(0)$, $I(1)$, or mutually cointegrated.

We have used quarterly data, over the recent floating exchange rate period, from 1973:1 to 1998:4, for 21 OECD countries – Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and the United States. Our results are consistent with most of the existing literature which mostly shows that, during the recent floating exchange rate period, the data are generally rejecting absolute PPP when the US dollar is used as the base currency – see, for example Serletis and Gogas (2000), who use the econometric frameworks of Fisher and Seater (1993) and King and Watson (1997) for studying long-run PPP propositions.

There is some evidence, however, in favor of long-run absolute purchasing power parity when the Japanese yen and the German mark are used as the base currencies. Our evidence regarding the case when the German mark is used as the base currency is consistent with Koedijk et al. (1998) who show, using a panel framework, that the evidence in favor of purchasing power parity is stronger for the German mark than for the US dollar. Our evidence, however, for the case when the Japanese yen is used as the base currency is inconsistent with the Koedijk et al. (1998) results which show the least evidence in favor of PPP when the yen is used as the numeraire. Our results seem to suggest that features of the Japanese economy (such as, for example, pricing to market and incomplete pass through) are potentially important for the theory of absolute PPP. In this regard, Engle (1999) has also argued that real exchange rate movements are due to variation in the common currency price of tradable goods.

Our evidence suggests that the choice of base currency is important in the analysis of long-run absolute PPP. On the other hand, we provide evidence that is supportive in favor of long-run relative purchasing power parity, regardless of our choice of base currency.

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Appendix A

See Tables 6–9.

Table 6
Bivariate tests of absolute PPP based on those specifications that minimize the BIC[a]

Country	Without trend						With trend					
	US		DM		Yen		US		DM		Yen	
Australia	[1,1]	0.87	[1,1]	2.89	[1,1]	1.72	[1,1]	3.69	[1,1]	3.80	[1,1]	1.72
Austria	[1,1]	1.23	[2,1]	3.56	[2,1]	3.69	[1,1]	3.80	[2,1]	3.84	[2,1]	5.27
Belgium	[1,2]	4.51	[1,1]	1.45	[2,3]	5.56	[1,2]	10.85	[1,1]	0.28	[2,3]	5.16
Canada	[1,1]	1.23	[1,1]	1.97	[1,1]	1.18	[1,1]	2.92	[1,1]	2.16	[2,1]	2.13
Denmark	[1,1]	1.89	[1,1]	4.67	[2,1]	5.25	[1,1]	1.61	[1,1]	2.17	[2,1]	4.24
Finland	[2,1]	2.44	[1,1]	11.25	[2,1]	5.32	[2,1]	3.47	[1,1]	6.62	[2,1]	4.44
France	[1,1]	3.89	[1,1]	4.65	[3,1]	8.54	[1,2]	6.10	[4,1]	11.25	[3,1]	7.40
Germany	[1,1]	1.25	–	–	[1,1]	0.58	[1,1]	1.98	–	–	[2,1]	4.75
Greece	[1,2]	2.29	[1,4]	3.65	[2,1]	3.47	[1,2]	3.15	[1,1]	4.59	[2,1]	3.81
Ireland	[2,2]	5.02	[1,1]	5.59	[2,1]	7.56	[2,2]	4.96	[1,1]	5.16	[2,1]	6.93
Italy	[1,1]	2.65	[1,4]	8.08	[2,1]	4.85	[1,1]	2.88	[1,4]	2.13	[2,1]	4.64
Japan	[1,1]	0.55	[1,1]	0.58	–	–	[1,1]	2.11	[2,1]	4.75	–	–
Netherlands	[1,1]	1.29	[3,2]	7.32	[2,1]	2.04	[1,1]	2.49	[1,2]	18.61	[2,1]	4.77
New Zealand	[1,1]	2.50	[1,1]	5.10	[1,1]	3.98	[1,1]	1.90	[1,1]	5.19	[1,1]	1.80
Norway	[1,1]	1.88	[1,1]	2.63	[2,1]	4.61	[1,1]	3.48	[1,1]	3.56	[2,1]	4.92
Portugal	[1,2]	3.40	[5,1]	8.68	[2,2]	4.48	[1,2]	4.40	[5,1]	8.21	[2,1]	2.82
Spain	[1,1]	1.17	[1,1]	2.70	[2,1]	4.63	[1,1]	1.51	[1,1]	3.45	[2,1]	4.29
Sweden	[1,1]	1.31	[1,1]	3.51	[2,1]	5.15	[1,1]	5.38	[1,1]	3.77	[2,1]	4.99
Switzerland	[1,1]	1.77	[1,1]	4.64	[1,1]	1.62	[1,1]	3.45	[1,1]	10.62	[1,1]	4.00
United Kingdom	[1,1]	2.80	[1,1]	3.78	[2,1]	4.82	[1,1]	2.55	[1,1]	2.73	[2,1]	3.70
United States	–	–	[1,1]	1.25	[1,1]	0.55	–	–	[1,1]	1.98	[1,1]	2.11

[a] Numbers in brackets indicate the optimal lag structure. For the case without trend, the 95% asymptotic critical value is 5.73 when all series are $I(1)$, 4.94 when they are $I(0)$, and falls in the interval [4.94, 5.73] when one series is $I(0)$ and one is $I(1)$ – see Pesaran et al. (1999, Table C1.iii). For the case with trend, the 95% asymptotic critical value is 7.30 when all series are $I(1)$, 6.56 when they are $I(0)$, and falls in the interval [6.56, 7.30] when one series is $I(0)$ and one is $I(1)$ – see Pesaran et al. (1999, Table C1.v).

Table 7
Bivariate tests of relative PPP based on those specifications that minimize the BIC[a]

Country	Without trend						With trend					
	US		DM		Yen		US		DM		Yen	
Australia	[1,1]	52.2	[1,1]	46.2	[1,1]	35.3	[1,1]	51.7	[1,1]	45.8	[1,1]	35.4
Austria	[1,1]	39.3	[1,1]	93.5	[1,1]	29.5	[1,1]	38.8	[1,1]	92.5	[1,1]	29.1
Belgium	[1,3]	40.9	[1,1]	32.5	[1,1]	26.9	[1,3]	40.8	[1,1]	33.4	[1,1]	26.9
Canada	[1,1]	42.3	[1,1]	37.4	[1,1]	30.4	[1,1]	41.8	[1,1]	37.5	[1,1]	30.6
Denmark	[1,1]	35.5	[1,1]	51.8	[1,1]	27.1	[1,1]	35.6	[1,1]	56.6	[1,1]	28.4
Finland	[1,1]	28.3	[1,8]	52.7	[1,1]	26.1	[1,1]	28.0	[1,8]	52.3	[1,1]	27.7
France	[1,1]	40.6	[1,1]	46.2	[1,1]	29.5	[1,1]	40.6	[1,1]	45.7	[1,1]	30.3
Germany	[1,1]	37.5	–	–	[1,1]	29.8	[1,1]	37.1	–	–	[1,1]	29.4
Greece	[1,1]	44.8	[1,1]	65.5	[1,1]	30.9	[1,1]	45.0	[1,1]	65.8	[1,1]	31.5
Ireland	[2,1]	30.7	[1,1]	51.2	[1,1]	25.2	[2,1]	37.1	[1,1]	52.3	[1,1]	26.1
Italy	[1,1]	35.4	[1,1]	45.3	[1,1]	25.0	[1,1]	35.0	[1,1]	61.8	[1,1]	25.7
Japan	[1,1]	32.6	[1,1]	29.8	–	–	[1,1]	32.3	[1,1]	29.3	–	–
Netherlands	[1,1]	36.4	[2,1]	49.0	[1,1]	26.8	[1,1]	36.0	[4,1]	39.2	[1,1]	26.4
New Zealand	[1,1]	34.1	[1,1]	54.1	[1,1]	42.4	[1,1]	36.4	[1,1]	53.8	[1,1]	46.9
Norway	[1,1]	45.5	[1,1]	38.2	[1,1]	28.6	[1,1]	45.0	[1,1]	37.8	[1,1]	28.3
Portugal	[1,1]	43.2	[1,1]	38.2	[1,1]	27.1	[1,1]	42.8	[1,1]	40.3	[1,1]	28.7
Spain	[1,1]	32.3	[1,1]	39.4	[1,1]	22.6	[1,1]	32.2	[1,1]	39.0	[1,1]	23.1
Sweden	[1,1]	33.6	[1,1]	35.6	[2,1]	24.8	[1,1]	33.2	[1,1]	36.3	[1,1]	24.5
Switzerland	[1,1]	41.4	[1,1]	53.6	[1,1]	37.7	[1,1]	41.0	[1,1]	53.7	[1,1]	37.1
United Kingdom	[1,1]	35.3	[1,1]	38.3	[1,1]	23.6	[1,1]	35.0	[1,1]	39.3	[1,1]	26.0
United States	–	–	[1,1]	37.5	[1,1]	32.6	–	–	[1,1]	37.1	[1,1]	32.3

[a] Numbers in brackets indicate the optimal lag structure. For the case without trend, the 95% asymptotic critical value is 5.73 when all series are $I(1)$, 4.94 when they are $I(0)$, and falls in the interval [4.94, 5.73] when one series is $I(0)$ and one is $I(1)$ – see Pesaran et al. (1999, Table C1.iii). For the case with trend, the 95% asymptotic critical value is 7.30 when all series are $I(1)$, 6.56 when they are $I(0)$, and falls in the interval [6.56, 7.30] when one series is $I(0)$ and one is $I(1)$ – see Pesaran et al. (1999, Table C1.v).

Table 8
Trivariate tests of absolute PPP based on those specifications that minimize the BIC[a]

Country	Without trend						With trend					
	US		DM		Yen		US		DM		Yen	
Australia	[1,1,2]	6.40	[1,1,1]	2.46	[1,1,1]	1.40	[1,1,2]	6.17	[1,1,1]	2.76	[1,1,1]	1.47
Austria	[1,1,1]	2.20	[2,1,1]	3.28	[2,1,1]	4.16	[1,1,1]	1.58	[1,1,1]	4.01	[2,1,1]	5.54
Belgium	[1,1,1]	3.36	[1,1,1]	0.62	[2,2,1]	4.10	[1,1,1]	4.83	[1,1,1]	4.64	[2,1,1]	5.75
Canada	[1,1,1]	2.53	[1,1,1]	3.17	[1,1,1]	3.20	[1,1,1]	2.57	[1,1,1]	0.78	[1,1,1]	2.55
Denmark	[1,1,1]	1.21	[1,1,1]	2.06	[2,1,1]	3.69	[1,1,1]	4.07	[1,1,1]	6.40	[2,1,1]	4.14
Finland	[2,1,1]	3.05	[1,1,1]	9.13	[2,1,1]	3.43	[2,1,1]	3.21	[4,6,6]	20.1	[2,1,1]	3.41
France	[1,1,2]	4.02	[4,1,2]	10.23	[2,1,1]	4.04	[1,1,2]	3.61	[4,1,2]	10.2	[1,1,1]	4.46
Germany	[1,1,1]	0.87	–	–	[2,1,1]	4.33	[1,1,1]	1.72	–	–	[2,1,1]	4.44
Greece	[1,1,1]	4.36	[1,2,2]	4.73	[2,1,1]	2.56	[1,1,1]	4.62	[1,1,2]	5.82	[1,1,1]	4.10
Ireland	[2,2,2]	3.87	[1,1,1]	3.93	[2,1,1]	4.79	[1,1,2]	8.13	[1,1,1]	3.20	[2,1,1]	4.65
Italy	[1,1,1]	3.00	[1,1,2]	4.58	[2,1,1]	3.61	[1,1,2]	5.76	[1,1,2]	3.99	[2,1,1]	3.78
Japan	[1,1,1]	2.37	[2,1,1]	4.33	–	–	[1,1,1]	2.85	[2,1,1]	4.44	–	–
Netherlands	[1,1,1]	0.99	[1,2,1]	12.2	[2,1,1]	4.91	[1,1,1]	1.58	[1,4,1]	15.08	[2,1,1]	4.90
New Zealand	[1,1,2]	4.30	[1,1,1]	3.24	[1,1,1]	2.50	[1,1,2]	6.28	[1,1,1]	3.75	[1,1,1]	1.68
Norway	[1,1,1]	3.10	[1,1,1]	3.45	[2,1,1]	3.33	[1,1,2]	5.46	[1,1,1]	2.55	[2,1,1]	3.10
Portugal	[1,2,2]	7.27	[5,1,1]	5.40	[1,1,1]	2.37	[1,2,2]	8.46	[5,1,1]	6.47	[2,1,1]	2.95
Spain	[1,1,1]	4.39	[1,1,1]	4.47	[2,1,1]	2.87	[1,1,1]	6.61	[1,1,1]	5.80	[2,1,1]	2.84
Sweden	[1,1,1]	4.93	[2,1,1]	4.85	[2,1,1]	3.59	[1,1,1]	4.28	[2,1,1]	4.52	[2,1,1]	3.50
Switzerland	[1,1,1]	1.60	[1,2,1]	10.2	[1,1,1]	3.46	[1,1,1]	1.25	[1,2,1]	10.30	[1,1,1]	4.34
United Kingdom	[1,1,1]	5.70	[1,1,1]	2.96	[2,1,1]	2.56	[1,1,2]	8.17	[1,1,1]	2.06	[2,1,1]	2.26
United States	–	–	[1,1,1]	0.87	[1,1,1]	2.37	–	–	[1,1,1]	1.72	[1,1,1]	2.85

[a] Numbers in brackets indicate the optimal lag structure. For the case without trend, the 95% asymptotic critical value is 4.85 when all series are $I(1)$, 3.79 when they are $I(0)$, and falls in the interval [3.79, 4.85] when one series is $I(0)$ and one is $I(1)$ – see Pesaran et al. (1999, Table C1.iii). For the case with trend, the 95% asymptotic critical value is 5.85 when all series are $I(1)$, 4.87 when they are $I(0)$, and falls in the interval [4.87, 5.85] when one series is $I(0)$ and one is $I(1)$ – see Pesaran et al. (1999, Table C1.v).

Table 9
Trivariate tests of relative PPP based on those specifications that minimize the BIC[a]

Country	Without trend						With trend					
	US		DM		Yen		US		DM		Yen	
Australia	[1,1,2]	35.7	[1,1,1]	26.2	[1,1,1]	22.9	[1,1,1]	38.4	[1,1,1]	26.0	[1,1,1]	22.6
Austria	[1,3,1]	28.0	[1,1,1]	62.2	[1,1,1]	19.7	[1,3,1]	32.0	[1,1,1]	62.0	[1,1,1]	19.5
Belgium	[1,1,1]	25.6	[1,1,1]	24.3	[1,1,1]	17.5	[2,1,1]	23.3	[1,1,1]	24.1	[1,1,1]	17.3
Canada	[1,1,1]	27.7	[1,1,1]	24.8	[1,1,1]	19.9	[1,1,1]	27.6	[1,1,1]	27.7	[1,1,1]	20.1
Denmark	[1,1,1]	24.3	[1,1,2]	38.9	[1,1,1]	18.65	[1,1,1]	24.1	[1,1,2]	39.3	[1,1,1]	18.4
Finland	[1,1,1]	18.6	[2,2,1]	10.7	[1,1,1]	18.1	[1,1,1]	18.9	[2,2,1]	10.9	[1,1,1]	18.1
France	[1,1,1]	27.8	[1,1,1]	30.0	[1,1,1]	20.0	[1,1,1]	30.3	[1,1,1]	29.8	[1,1,1]	19.8
Germany	[1,1,1]	25.3	–	–	[1,1,1]	19.4	[1,1,1]	25.4	–	–	[1,1,1]	19.2
Greece	[1,1,1]	30.0	[1,1,2]	44.0	[1,1,1]	21.3	[1,1,1]	29.6	[1,1,1]	45.1	[1,1,1]	21.0
Ireland	[2,1,1]	20.0	[1,1,1]	31.5	[1,1,1]	17.8	[2,1,1]	20.0	[1,1,1]	31.2	[1,1,1]	17.5
Italy	[1,1,1]	23.0	[1,1,3]	30.7	[1,1,1]	17.4	[1,1,1]	23.1	[1,3,3]	38.7	[1,1,1]	17.1
Japan	[1,1,1]	21.4	[1,1,1]	19.4	–	–	[1,1,1]	21.3	[1,1,1]	19.2	–	–
Netherlands	[1,1,1]	24.7	[4,1,1]	24.5	[1,1,1]	17.0	[1,3,1]	24.8	[4,1,1]	26.7	[1,1,1]	16.9
New Zealand	[1,1,4]	29.3	[1,1,1]	35.0	[1,1,1]	29.3	[1,1,2]	25.3	[1,1,1]	34.9	[1,1,1]	30.5
Norway	[1,1,1]	30.1	[1,1,1]	25.4	[1,1,1]	18.9	[1,1,1]	30.3	[1,1,1]	27.0	[1,1,1]	18.8
Portugal	[1,1,1]	28.9	[1,1,1]	24.8	[1,1,1]	18.6	[1,1,1]	28.7	[1,1,1]	26.9	[1,1,1]	18.6
Spain	[1,1,1]	21.4	[1,1,2]	27.8	[1,1,1]	15.7	[1,1,1]	21.1	[1,1,2]	27.8	[1,1,1]	15.6
Sweden	[1,1,1]	21.9	[1,1,2]	24.5	[1,1,1]	16.2	[1,1,1]	22.0	[1,1,2]	24.5	[1,1,1]	16.1
Switzerland	[1,1,1]	29.8	[1,1,1]	47.1	[1,1,1]	24.9	[1,1,1]	29.8	[1,1,1]	47.1	[1,1,1]	25.6
United Kingdom	[1,1,1]	23.3	[1,1,1]	24.3	[1,1,1]	17.8	[1,1,1]	23.5	[1,1,1]	25.1	[1,1,1]	17.9
United States	–	–	[1,1,1]	25.3	[1,1,1]	21.4	–	–	[1,1,1]	25.4	[1,1,1]	21.3

[a] Numbers in brackets indicate the optimal lag structure. For the case without trend, the 95% asymptotic critical value is 4.85 when all series are $I(1)$, 3.79 when they are $I(0)$, and falls in the interval [3.79, 4.85] when one series is $I(0)$ and one is $I(1)$ – see Pesaran et al. (1999, Table C1.iii). For the case with trend, the 95% asymptotic critical value is 5.85 when all series are $I(1)$, 4.87 when they are $I(0)$, and falls in the interval [4.87, 5.85] when one series is $I(0)$ and one is $I(1)$ – see Pesaran et al. (1999, Table C1.v).

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