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European Economic Integration and Purchasing Power Parity：Empirical Evidence using Threshold Unit Root Tests

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Abstract

The purpose of this research is to investigate the validity of the purchasing power parity (PPP) hypothesis established for Germany and Great Britain, using the US dollar as numeraire currencies. The research is divided into three periods: the European Monetary System (EMS:1979) Post-Bretton Woods Agreements, the Maastricht Treaty Meeting (1992) and the beginning of the adoption of the Euro. A nonlinear threshold unit root test is used for the bilateral real exchange rates (RERs). The main discovery is a non-linear steady state during the period of time that Germany, a Eurozone country, used the Euro and a change in the exchange rate showed a mean reversion to the equilibrium state under purchasing power parity. As for Great Britain, a non-Eurozone country, a linear and unsteady state is seen. From this, it is concluded that the speed of economic integration in countries within the Eurozone should accelerate and converge, to validate the PPP hypothesis established.

Keywords: Purchasing Power Parity (PPP)；Nonlinear Threshold Unit Root Test；Bilateral Real Exchange Rates (RERs)；Economic Integration.
JEL Classification Codes: F31；F33；G15；C22

1. Introduction

The 1980s and 90s witnessed a rapid integration of international capital and financial markets. The driving force for the globalization of financial markets initially came from the governments of major countries that had begun to deregulate their foreign exchange and capital markets. International trade also continued to expand and was liberalized at both the global and regional levels. At the global level, the General Agreement on Tariffs and Trade (GATT), brokered by the World Trade Organization (WTO), had been successful in gradually eliminating and reducing tariffs, subsidies, quotas and other barriers to trade. At the regional level, formal arrangements between countries had been instituted to promote economic integration. The European Union (EU) is a prime example of one of these arrangements. To promote further integration, the Euro was introduced for eleven member countries of

the EU, on January 1, 1999, as a result of the monetary integration process set down by the Maastricht Treaty of 1992 and the European Monetary System of 1979. These developments have had a major impact on the determination of price levels and exchange rates in the euro area.

One major criterion for EU membership is inflation convergence and exchange rate stability with other member states. According to the Purchasing Power Parity (PPP) theory, there exists a proportionate relationship between the nominal exchange rate and the relative price ratio. The real exchange rates should revert to a constant level, over time, if the PPP holds. The integrity of PPP has crucial implications for international trade and multinational business. If PPP holds and the differential inflation rates between countries are exactly offset by exchange rate changes, countries' competitive positions in world markets are be systematically affected by exchange rate changes. The recent trends toward regional integration and the adoption of the euro provide an almost ideal case study for a reappraisal of the PPP theory.

There is a large body of literature concerning the PPP hypothesis, which shows mixed results from using a variety of methodologies. In recent literature, one of the most popular methods of testing the PPP is by applying the standard Dickey and Fuller (1979) unit root test to the bilateral real exchange rates. Rejection of the unit root hypothesis implies that the real exchange rate is stationary and the deviation from PPP is temporary. The PPP hypothesis is supported in the long-term. However, many studies (see for example, Adler and Lehmann, 1983; Taylor, 1988; Meese and Rogoff, 1988; Abuaf and Jorion, 1990; Kim, 1990) have applied this methodology and failed to reject unit roots in real exchange rates.

Campbell and Perron (1991) and Edison et al., (1997) argued that the main reason for the failure of the univariate unit root tests to reject was due to the small sample size of the real exchange rate variables. Therefore, the empirical tests showed a low power problem. The solution increases increase the sample size by using panel approach. The empirical studies using the panel approach (such as OH, 1996; Wu, 1996; Papell, 1997; Coakley and Fuertes, 1997; Lothian, 1998; Husted and MacDonald, 1998; Koedijk, 1998; Taylor and Sarno, 1998; Fleissig and Strauss, 2000; Chiu, 2002; Papell, 2002; Banerjee et al., 2005) do not reject stationary real exchange rates and support the PPP hypothesis.

However, as Koedijk et al., (2004) pointed out in their study, there are few empirical studies of PPP inside the Eurozone (also refer to Alquist and Chinn, 2002; Gadea et al., 2004; Lopez and Papell, 2007) and that is why the PPP hypothesis has only limited support. Further research on the Eurozone, especially after the commencement of the euro, are required in order to increase knowledge of the empirical validity of the PPP hypothesis. Recently, Zhou et al., (2008) pointed out that if some real exchange rates tend to exhibit a nonlinear mean reversion process, the alternative hypothesis of linear stationarity in the ADF tests and panel unit root tests could be misspecified. Therefore, they used a new nonlinear unit root test to investigate the bilateral real exchange rates of European and other industrial countries during the period of the adoption of the Euro, in 1998, for the French Franc and German Deutschmark, with the US dollar acting as the numeraire currency. The empirical results strongly suggest that the PPP hypothesis is even more valid for European Union countries, after the adoption of the Euro, compared to past research on industrial countries.

To the best of the authors' knowledge, there is very little literature on the direct use of the nonlinear unit root test to investigate the bilateral real exchange rates in Eurozone countries. This research conducts a simultaneous investigation of the non-stationarity and nonlinearity of real exchange rates by applying the methodology proposed by Caner and Hansen (2001). With respect to the literature on the PPP hypothesis for the Eurozone, the potential contributions of this paper are as follows. Firstly, in relation to the research of Rogers (2007), the validity of the PPP hypothesis is investigated in conjunction with the major events in the adoption of the Euro. In order to better understand the PPP hypothesis, the sample considers four periods, the entire sample period (from 1981/01 to 2009/03), the Euro adoption period (from 1999/01 to 2009/03) and two periods before the Euro (from 1981/01 to 1992/01, which is before the Maastricht Treaty, and from 1992/02 to 1998/12,

which is the period after the Maastricht Treaty). Secondly, by applying a more sophisticated econometric method, which simultaneous considers the non-stationarity and nonlinearity of real exchange rates, a threshold effect and threshold unit root testing is proposed to describe the nonlinearity and unit root. Thirdly, the PPP hypothesis is analyzed for three regions and for three currencies, namely the US dollar, the German Deutschmark, and the British pound. The United States is the world's largest economy and is involved in huge trade with major European countries. Germany is one of the most important countries in the European area and is the founding country and major advocate for the EU and the Euro zone. The UK is in the EU system, but does not the Euro zone.[1] The use of these three representative currencies allows the investigation of the possibility of different patterns of mean reversion of the real exchange rate for Eurozone countries and non-Eurozone countries.

The organizational structure of this paper is as follows. Section II details the methodology used in this study. Section III describes the data and presents the empirical results. The conclusion is drawn in the final Section.

2. Methodology

2.1. Model Specification

This section follows the methodology proposed by Caner and Hansen (2001) to test the effect of a threshold on the unit root process of the real exchange rate series, γ_t. A two regime TAR(*k*) model is used, as follows:

$$\Delta\gamma_t = \theta_1' x_{t-1} I_{\{Z_t\text{-}1\le\lambda\}} + \theta_2' x_{t-1} I_{\{Z_t\text{-}1>\lambda\}} + \varepsilon_t,\ t = 1, \ldots, T \tag{1}$$

where, $x_{t-1} = (\gamma_{t-1}\ \Pi'_t\ \Delta\gamma_{t-1} \ldots \Delta\gamma_{t-k})'$, $I_{\{\bullet\}}$ is the indicator function, ε_t represents an independent and identical disturbance term, $z_{t-1} = \gamma_{t-1} - \gamma_{t-m}$ is the threshold variable for $m \ge 1$, Π'_t denotes a vector of the deterministic variables, including an intercept and possibly a linear time trend, λ is a threshold parameter and $k \ge 1$ is the autoregressive unit root lag term. The components, θ_1 and θ_2, can be partitioned as follows:

$$\theta_1 = (\rho_1 \quad \beta_1 \quad \alpha_1)' \text{ and } \theta_2 = (\rho_2 \quad \beta_2 \quad \alpha_2)', \tag{2}$$

Where ρ_1 and ρ_2 are scalar terms, β_1 and β_2 have the same dimensions as Π_t and α_1 and α_2 are k-vectors. Thus (ρ_1, ρ_2) are the slope the coefficients on $(\Delta\gamma_{t-1},...,\Delta\gamma_{t\text{-}k})$ for the two different regimes and (β_1, β_2) are the slopes on the deterministic components.

2.2. Test for a threshold effect

The threshold effect, measured from eq. (1), has the null hypothesis, $H_0 : \theta_1 = \theta_2$. By using the Wald statistic, it is seen that $W_T = W_T(\hat{\lambda}) = \sup_{\lambda\in\Lambda} W_T(\lambda)$. If the null hypothesis can not be rejected, the time series includes no threshold effect. In this situation, the two vectors of the coefficients are identical for both regimes $(\theta_1 = \theta_2)$.

2.3. Test for a Threshold unit Root

The threshold unit root tests employ two Wald test statistics, as follows. Initially, the tow-sided Wald test statistic, which has the null hypothesis of a unit root, $H_0 : \rho_1 = \rho_2 = 0$, is tested against the

[1] The UK used to be a member of the Exchange Rate Mechanism (ERM) system, which is a fixed exchange rate system in Europe. However, On 16 September 1992, known in the UK as Black Wednesday, the British was forced to withdraw from the fixed exchange rate system, due to a rapid fall in its value.

alternative, $H_1 : \rho_1 \neq$ or $\rho_2 \neq 0$.The parameters, ρ_1 and ρ_2, of eq. (1) control the regime-dependent unit root process of the real exchange rates. When the hypothesis, H_0, holds, meaning the real exchange rate has a unit root, the real exchange rate series can be depicted as a rejection of the PPP. This statistic is:

$$R_{2T} = t_1^2 + t_2^2, \tag{3}$$

where t_1 and t_2 are the *t* ratios for $\hat{\rho}_1$ and $\hat{\rho}_2$ from the ordinary least squares regression of eq. (1). However, Caner and Hansen (2001) claimed that the two-sided Wald statistic may have less power than the one-sided Wald statistic of this test. In order to address this problem, they recommend the one-sided Wald statistic as follows:

$$R_{1T} = t_1^2 I_{\{\hat{\rho}_1<0\}} + t_2^2 I_{\{\hat{\rho}_1<0\}}, \tag{4}$$

Where R_{1T} tests H_0 against the one-sided alternative, $\rho_1 < 0$ or $\rho_2 < 0$. This testing procedure is used in the following empirical work.

3. Empirical Results

3.1. Data and Basic Model

This study's sample consists of monthly nominal exchange rates and consumer price indices for Germany, the UK and the US, extracted from *Datastream International*, for the period from January 1981 to March 2009. Nominal bilateral exchange rates were converted into real bilateral exchange rates by incorporating the consumer price indices adjustment. The real exchange rate is calculated by:

$$RER_s = e + P^* - P, \tag{5}$$

where RER_s is the real exchange rate, e is the logarithm of the nominal exchange rate, P^* represents the logarithm of the foreign price index and P is the logarithm of the domestic price index.

Table 1 and Table 2 show the results from the threshold test and threshold unit root for the bilateral RERs, respectively, with the US dollar as the numeraire currency.

3.2. Results from the Threshold Effect

This section applies the Wald test, W_T, to examine whether or not the linear autoregressive model can be rejected in favor of a threshold model. The results of the Wald test and the bootstrap critical values generated at conventional levels of significance are reported in Table 1 and 2. The bootstrap p-value for threshold variables of the form, $Z_{t-1} = \gamma_{t-1} - \gamma_{t-m}$, for delay parameters, m, ranges from 1 to 12. Since the parameters, *m*, are generally unknown, m is chosen using the criteria of the empirical procedure of Caner and Hansen (2001). Caner and Hansen (2001) suggested making m endogenous by selecting the least squares estimate of *m* that minimizes the residual variance. The best fitting model is determined according to the W_T statistic, which selects a value of *m* that maximizes the W_T statistic.

In Table1 (Period I: 1981.1 ~ 1992.1), it is seen that the W_T statistic is maximized for Germany-U.S. (30.34) when $m = 12$ and for United Kingdom-U.S. (37.57) when $m = 7$. During period II: 1992.2 ~ 1998.12, the W_T statistic is maximized for Germany-U.S. when $m = 4$ and for United Kingdom-U.S. when $m = 7$. The W_T statistic is maximized for Germany-U.S. when $m = 4$ and for United Kingdom-U.S. when $m = 2$, for period III (1999.1~ 2009.3). In the entire sample period (Period IV: 1981.1~2009.3), the W_T statistic is maximized for Germany-U.S. when $m = 12$ and for United Kingdom-U.S. when $m = 4$. Taken together, these results provide strong statistical evidence against the null hypothesis of linearity of at least 5% in Germany-U.S. from 1992.2 to 2009.3, and United kingdom-U.S. within the EMS period.

Table 1: Threshold test results for the Bilateral Real Exchange Rates with the US Dollar as Numeraire

	Bootstrap critical values (%)																							
Country	***m***	W_T	**10**	**5**	**1**	***p***	***m***	W_T	**10**	**5**	**1**	***p***	***m***	W_T	**10**	**5**	**1**	***p***	***m***	W_T	**10**	**5**	**1**	***p***
	Period I:1981.1 ~ 1992.1						**Period II:1992.2 ~ 1998.12**						**Period III:1999.1~ 2009.3**						**Period IV:1981.1~2009.3**					
Germany	1	17.94	67.93	86.09	134.66	0.84	1	29.24	34.82	38.51	44.97	0.23	1	38.10	33.08	35.78	41.72	0.03	1	28.15	38.86	46.98	71.51	0.28
	2	17.18	63.09	91.56	129.29	0.86	2	22.29	33.65	37.14	43.48	0.59	2	34.61	32.07	35.29	38.93	0.06	2	33.21	34.86	43.20	64.89	0.12
	3	23.97	57.55	74.69	111.78	0.59	3	25.78	33.11	36.67	43.65	0.37	3	50.26	32.14	35.04	40.70	0.00	3	36.89	35.44	45.45	65.57	0.09
	4	26.89	61.89	86.80	124.39	0.46	**4**	**34.59**	**33.20**	**38.60**	**49.39**	**0.08**	**4**	**59.54**	**31.44**	**33.60**	**38.16**	**0.00**	4	35.97	38.62	48.20	72.13	0.13
	5	25.83	57.12	85.65	111.51	0.51	5	23.31	35.01	38.89	47.46	0.53	5	52.26	33.17	36.74	40.48	0.00	5	40.43	38.77	48.61	67.79	0.09
	6	23.94	55.01	75.00	107.81	0.56	6	26.80	35.30	39.81	48.11	0.35	6	44.31	32.33	35.95	41.32	0.00	6	44.94	38.10	46.06	73.57	0.05
	7	20.81	54.16	77.31	117.89	0.66	7	25.13	34.98	38.75	45.96	0.40	**7**	50.23	32.59	34.58	43.89	0.00	**7**	37.72	37.56	45.59	67.71	0.10
	8	27.58	55.27	78.01	113.42	0.43	8	20.51	33.65	37.80	45.46	0.68	8	43.56	32.08	35.17	39.74	0.00	8	39.47	39.43	46.82	62.29	0.10
	9	26.37	61.31	76.65	109.27	0.46	9	21.77	34.08	37.04	46.44	0.61	9	39.29	32.22	34.95	40.55	0.02	9	41.23	38.24	45.60	61.37	0.08
	10	23.63	57.91	80.53	117.82	0.58	10	21.33	34.31	37.06	46.06	0.63	10	33.32	31.76	34.80	40.96	0.08	10	44.62	36.76	45.05	65.36	0.06
	11	29.81	59.79	85.35	126.18	0.36	11	19.41	33.61	38.02	47.24	0.76	11	35.29	32.42	35.39	44.79	0.05	11	46.92	36.11	44.68	63.92	0.04
	12	**30.34**	**60.50**	**79.05**	**113.36**	**0.35**	12	22.80	34.39	39.12	47.25	0.57	12	34.03	31.36	34.04	41.22	0.05	12	**47.66**	**35.78**	**43.70**	**62.97**	**0.03**
U.K	1	18.33	34.06	36.14	46.79	0.84	1	25.14	35.87	40.98	49.89	0.41	1	16.48	32.80	36.64	45.58	0.94	1	22.39	30.85	33.49	41.51	0.52
	2	24.36	35.22	39.09	45.60	0.50	2	27.70	35.79	40.83	47.92	0.32	**2**	**25.71**	**32.29**	**35.57**	**40.86**	**0.34**	2	18.15	30.43	33.60	38.58	0.82
	3	27.43	35.05	38.29	44.87	0.28	3	24.07	35.34	40.67	49.21	0.49	3	25.07	32.76	35.73	42.53	0.37	3	24.69	29.70	32.08	35.91	0.31
	4	31.56	34.71	38.79	46.15	0.17	4	27.06	35.64	39.50	47.84	0.33	4	19.76	33.31	36.32	40.28	0.75	**4**	**27.53**	**30.42**	**33.14**	**40.88**	**0.21**
	5	28.76	33.51	37.97	44.67	0.28	5	18.16	35.71	39.75	50.14	0.88	5	22.18	32.98	35.49	42.05	0.62	5	22.58	31.56	33.54	42.15	0.52
	6	31.75	34.20	36.77	43.18	0.16	6	23.02	35.86	40.19	49.38	0.60	6	14.80	32.38	34.96	41.49	0.98	6	24.13	30.33	32.60	40.06	0.35
	7	**37.57**	**34.64**	**38.61**	**45.28**	**0.06**	**7**	**33.35**	**35.24**	**37.83**	**48.31**	**0.15**	7	19.45	32.85	37.06	43.44	0.79	**7**	25.23	30.51	34.40	39.42	0.29
	8	28.64	33.64	37.59	43.94	0.25	8	29.35	35.52	40.94	50.87	0.26	8	17.26	33.33	37.30	45.24	0.90	8	22.29	30.08	33.53	39.47	0.48
	9	29.96	34.43	37.70	44.04	0.21	9	26.76	35.28	39.34	45.44	0.36	9	23.83	32.04	36.07	46.71	0.47	9	16.70	30.11	33.04	37.65	0.87
	10	23.58	33.13	37.20	45.98	0.48	10	26.82	34.35	38.52	43.13	0.37	10	20.13	32.35	34.61	42.46	0.74	10	19.53	30.39	32.90	36.70	0.70
	11	18.35	33.37	36.41	45.55	0.84	11	18.56	36.09	41.20	50.11	0.83	11	21.21	31.64	35.31	44.83	0.64	11	20.78	30.74	33.28	38.95	0.62
	12	21.60	32.17	35.30	45.06	0.62	12	17.08	35.37	39.71	45.28	0.90	12	19.13	32.06	35.23	46.15	0.79	12	16.99	29.51	31.52	35.62	0.84

Notes: P represents Bootstrap *p*-value

Table 2: Threshold unit root test for the Bilateral Real Exchange Rates with the US Dollar as Numeraire

	Bootstrap critical values (%)																							
Country	***m***	W_T	**10**	**5**	**1**	***p***	***m***	W_T	**10**	**5**	**1**	***p***	***m***	W_T	**10**	**5**	**1**	***p***	***m***	W_T	**10**	**5**	**1**	***p***
	Period I:1981.1 ~ 1992.1						**Period II:1992.2 ~ 1998.12**						**Period III:1999.1~ 2009.3**						**Period IV:1981.1~2009.3**					
Germany	1	8.81	13.92	19.60	39.94	0.17	1	25.56	3.26	5.31	8.40	0.00	1	7.26	9.76	12.61	17.75	0.21	1	7.29	11.03	15.23	27.59	0.22
	2	4.21	14.05	20.04	38.69	0.44	2	13.51	3.33	5.38	8.66	0.00	2	6.39	10.06	12.41	15.51	0.28	2	5.82	11.11	15.18	28.88	0.34
	3	11.80	13.73	22.39	37.32	0.13	3	5.84	3.87	6.21	11.98	0.06	3	8.04	10.01	12.25	17.52	0.16	3	5.60	12.03	16.96	25.91	0.35
	4	10.36	13.87	18.68	35.02	0.16	**4**	**4.38**	**3.57**	**6.09**	**12.07**	**0.07**	**4**	**12.69**	**10.00**	**12.73**	**18.95**	**0.05**	4	5.55	11.32	17.06	26.35	0.36
	5	0.92	13.77	18.79	32.35	0.79	5	11.19	3.45	5.55	12.38	0.01	5	4.32	10.86	12.86	17.42	0.47	5	6.49	11.26	15.92	25.42	0.29
	6	7.58	15.58	22.04	52.03	0.28	6	5.70	3.39	5.55	11.38	0.05	6	3.15	11.82	14.50	19.19	0.58	6	15.02	12.40	16.78	26.72	0.07
	7	8.15	17.00	23.40	51.21	0.29	7	5.24	3.55	6.03	12.75	0.07	**7**	5.80	11.06	14.11	18.58	0.36	**7**	9.25	11.42	17.16	24.30	0.16
	8	3.47	14.18	19.83	53.04	0.54	8	4.66	4.21	6.56	11.40	0.09	8	2.26	12.84	14.71	19.20	0.68	8	13.92	11.51	16.19	24.48	0.08
	9	3.87	15.75	24.09	54.08	0.51	9	8.39	3.94	6.56	11.62	0.03	9	3.51	12.49	15.42	19.44	0.55	9	12.24	11.94	16.23	27.13	0.10
	10	5.12	16.46	26.06	54.90	0.42	10	9.44	4.16	6.77	13.13	0.03	10	4.50	11.93	14.46	19.73	0.52	10	9.72	11.32	16.24	26.22	0.17
	11	9.80	18.51	26.82	69.59	0.23	11	10.41	4.41	6.67	9.57	0.01	11	6.40	11.71	14.35	18.16	0.37	11	13.66	12.24	15.71	28.95	0.07

Table 2: Threshold unit root test for the Bilateral Real Exchange Rates with the US Dollar as Numeraire - continued

	12	**11.53**	**18.37**	**25.44**	**72.46**	**0.20**	12	13.43	4.35	6.68	12.50	0.01	12	5.14	12.00	13.24	21.05	0.45	**12**	**14.37**	**12.45**	**15.71**	**28.26**	**0.07**
U.K	1	3.88	8.93	11.53	16.28	0.45	1	8.34	9.69	12.09	19.59	0.14	1	2.58	8.68	10.60	14.74	0.58	1	5.06	8.49	10.75	15.24	0.33
	2	4.65	9.11	11.63	17.23	0.37	2	3.61	9.41	11.98	18.64	0.47	**2**	**0.87**	**8.87**	**12.03**	**16.28**	**0.82**	2	5.22	8.89	11.21	15.10	0.28
	3	4.60	9.23	12.06	15.90	0.38	3	2.38	10.95	13.87	18.14	0.58	3	8.69	9.40	11.42	15.43	0.12	3	10.09	8.45	11.07	15.07	0.06
	4	4.95	9.69	12.33	18.59	0.37	4	2.70	10.88	13.70	18.40	0.56	4	1.77	9.29	10.97	15.95	0.69	**4**	**4.35**	**8.66**	**10.26**	**15.70**	**0.41**
	5	5.16	9.66	11.58	16.29	0.34	5	1.31	10.52	13.30	20.96	0.72	5	2.36	8.98	10.86	15.00	0.62	5	2.97	8.27	9.96	13.85	0.58
	6	8.30	9.47	11.60	17.36	0.15	6	2.04	11.99	14.12	17.89	0.66	6	1.95	9.23	11.57	15.76	0.71	6	5.13	9.08	11.33	14.11	0.33
	7	**12.24**	**10.06**	**12.52**	**17.28**	**0.06**	**7**	**2.58**	**11.53**	**13.53**	**17.72**	**0.63**	7	2.68	9.48	11.57	14.77	0.62	**7**	4.22	8.56	9.75	15.03	0.43
	Bootstrap critical values (%)																							
	Period I:1981.1 ~ 1992.1						**Period II:1992.2 ~ 1998.12**						**Period III:1999.1~ 2009.3**						**Period IV:1981.1~2009.3**					
	8	5.60	10.04	13.35	19.54	0.34	8	2.80	11.65	13.58	19.96	0.59	8	2.81	9.32	11.78	16.57	0.60	8	2.18	8.37	10.18	13.50	0.71
	9	7.04	10.11	13.10	20.17	0.24	9	4.32	11.82	15.53	22.11	0.47	9	1.86	9.70	11.34	15.54	0.73	9	2.81	8.62	10.69	13.79	0.64
	10	3.91	10.95	13.08	17.88	0.49	10	3.79	13.00	15.58	21.56	0.53	10	0.72	9.19	11.02	16.50	0.87	10	4.25	8.17	9.92	13.67	0.42
	11	3.18	10.29	13.38	18.78	0.56	11	0.48	12.64	15.03	18.98	0.85	11	2.25	9.51	11.61	15.54	0.69	11	2.31	7.99	9.64	15.31	0.68
	12	8.46	10.31	13.16	19.67	0.16	12	2.07	12.45	15.45	18.62	0.70	12	1.45	9.85	12.29	17.75	0.78	12	5.17	8.68	10.83	14.47	0.33

Notes: P represents Bootstrap *p*-value

3.3. Results from the Threshold Unit Root Tests

The threshold unit root properties of RERs are then investigated using the R_{1T} statistic for each delay parameter, m, from 1 to 12, with particular attention to the results obtained from eq.(4). The R_{1T} test results, as well as the bootstrap critical value at the bootstrap p-value, are reported in table 2. The unit root null hypothesis is rejected for Germany/U.S. from period II to IV[1] and for U.K./U.S. in period I, at the 10% confidence level[2].

Overall, these test results imply that convergence toward PPP in Germany and other EU countries, especially those in the euro area, tends to be nonlinear. It is also probably linear for the non-Eurozone countries, such as the United Kingdom. (Zhou et al., 2008)

4. Conclusions

This paper analyzes whether PPP holds better in the years after the adoption of the euro. The research sample consists of four periods: the entire sample period (Period IV: 1981.1–2009.3), the period of the adoption of the Euro (Period III: 1999.1–2009.3) and the period before the Euro was used (Period I: 1981.1–1992.1, Period II: 1992.2–1998.12). Nonlinear threshold unit root testing was used to test the bilateral real exchange rates of Euro and non-Euro countries.

In summary, when observing periods II, III and IV and individually comparing the empirical results with the US dollar as the numeraire currency show that the validity of the PPP hypothesis is established for Euro countries and nonlinear stationarity appears after the adoption of the Euro. This implies that the deviations in exchange rate revert towards the PPP equilibrium, but these are linear for the U.K., which is a non-Euro industrial country. As mentioned previously in this paper, trade barriers and interference in international markets creates nonlinearity. Establishing the validity of the PPP hypothesis is useful as a reference for policymakers in major Euro countries when making exchange rate adjustment decisions. It is thereby concluded that the speed of economic integration in Eurozone countries accelerates and converges to the point where the validity of the PPP hypothesis is established.

References

[1] Abuaf, N. and Jorion, P. (1990) Purchasing power parity in the long run. *The Journal of Finance*, 45, 157–174.

[2] Adler, M. and Lehmann, B. (1983) Deviations from purchasing power parity in the long run. *The Journal of Finance*, 38, 1471–1487.

[3] Alquist, R. and Chinn, M. D. (2002) The Euro and the productivity puzzle: An alternative interpretation. *Working Paper*.

[4] Banerjee, A., Marcellino, M. and Osbat, C. (2005) Testing for PPP: should we use panel methods? *Empirical Economics*, 30, 77-91.

[5] Campbell, J. Y. and Perron, P. (1991) Pitfalls and opportunities: what macroeconomists should know about unit roots. *NBER Macroeconomics Annual*, 6: 141-220.

[6] Caner, M. and Hansen, B. E. (2001) Threshold autoregression with a unit root. *Econometrica*, 69, 1555–1596.

[7] Chiu, R. L. (2002) Testing the purchasing power parity in panel data. *International Review of Economics and Finance*, 11, 349-362.

[1] In period I (1990s) German unification may have slightly slowed the convergence toward PPP.

[2] There are two main explanations for the existence of nonlinearity in real exchange rates. One potential explanation arises from nonlinearity in international goods arbitrage, because of factors such as transportation costs and trade barriers, which result in a price gap between similar goods traded in spatially separated markets. It may also be due to official interventions in the foreign exchange market, which might cause the nominal and real exchange rates to move away from the equilibrium levels.

[8] Coakley, J. and Fuertes, A. M. (1997) New panel unit root tests of PPP. *Economics Letters*, 57, 17-22.
[9] Dickey, D. A. and Fuller, W. A. (1979) Distribution of the estimators for autoregressive time series with a unit root. *Journal of the American Statistical Association*, 74, 427–431.
[10] Edison, H. J., Gagnon, J. E. and Melick, W. R. (1997) Understanding the empirical literature on purchasing power parity: the post-Bretton Woods era. *Journal of International Money and Finance*, 16, 1-17.
[11] Fleissig, A. R. and Strauss, J. (2000) Panel unit root tests of purchasing power parity for price indices. *Journal of International Money and Finance*, 19, 489-506.
[12] Gadea, M., Montanes, A. and Reyes, M. (2004) The European Union and the US dollar: from Post-Bretton-Woods to the Euro. *Journal of International Money and Finance*, 23, 1109–1136.
[13] Husted, S. and MacDonald, R. (1998) Monetary-based models of the exchange rate: a panel perspective. *Journal of International Financial Markets, Institutions and Money*, 8, 1-19.
[14] Kim, Y. (1990) Purchasing power parity in the long-run: a cointegration approach. *Journal of Money Credit and Banking*, 22, 491–503.
[15] Koedijk, K. G. (1998) The pendulum of exchange rate economics. *Journal of International Money and Finance*, 17, 1–3.
[16] Koedijk, K. G., Tims, B. and van Dijk, M. A. (2004) Purchasing power parity and the Euro area. *Journal of International Money and Finance*, 23, 1081-1107.
[17] Lopez, C. and Papell, D. H. (2007) Convergence to purchasing power parity at the commencement of the Euro. *Review of International Economics*, 15, 1–16.
[18] Lothian, J. R. (1998) Some new stylized facts of floating exchange rates. *Journal of International Money and Finance*, 17, 29–39.
[19] Meese, R. and Rogoff, K. (1988) Was it real? The exchange rate-interest differential relation over the modern floating-rate period. *The Journal of Finance*, 43, 933–948.
[20] Oh, K. Y. (1996) Purchasing power parity and unit root test using panel data. *Journal of International Money and Finance*, 15, 405–418.
[21] Papell, D. H. (1997) Searching for stationarity: purchasing power parity under the current float. *Journal of International Economics*, 43, 313–332.
[22] Papell, D. H. (2002) The great appreciation, the great depreciation, and the purchasing power parity hypothesis. *Journal of International Economics*, 57, 51-82.
[23] Rogers, J. H. (2007) Monetary union, price level convergence, and Inflation: how close is Europe to the USA? *Journal of Monetary Economics*, 54: 785–796.
[24] Taylor, M. P. (1988) An empirical examination of long-run purchasing power parity using cointegration techniques. *Applied Economics*, 20, 1369–1381.
[25] Taylor, M. P. and Sarno, L. (1998) The behaviour of real exchange rates during the post-Bretton Woods period. *Journal of International Economics*, 46, 281–312.
[26] Wu, Y. (1996) Are real exchange rates nonstationary? Evidence from a panel-data test. *Journal of Money, Credit and Banking*, 28, 54–63.
[27] Zhou, S., Bahmani-Oskooee, M. and Kutan, A. M. (2008) Purchasing power parity before and after the adoption of the Euro. *Review of World Economics*, 144, 134-150.