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Exchange Rate Modelling in Ghana: Do the Purchasing Power Parity and Uncovered Interest Parity Conditions Hold Jointly?

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Abstract

We employ the cointegration and Vector Error Correction methodology to explore exchange rate modelling in Ghana by considering the interactions between the goods and capital asset markets using monthly data spanning from 1997:1 to 2007:12. The empirical evidence supports a long-run relationship between prices, interest rates, and exchange rates in which the signs are consistent with the joint validity of the unrestricted PPP and UIP conditions. Further likelihood ration tests based on the cointegration vector show that the strict forms of the PPP and UIP conditions between Ghana and the USA do not hold as stationary relations. The findings suggest that the interactions between the goods and capital asset markets matter for the conduct of monetary policy and exchange rate modelling in Ghana.

Keywords: Exchange Rate Modelling, Multivariate Cointegration Analysis, Purchasing Power Parity, Uncovered Interest Parity

1. Introduction

Due to the central roles played by international parity conditions such as purchasing power parity (PPP) and uncovered interest rate parity (UIP) in the modelling of exchange rates, prices and interest rates, researchers have made considerable efforts to test their empirical validity. A substantial fraction of the empirical evidences for the equilibrium relationships have failed to establish whether the exchange rate is determined by the level of prices as claimed by the PPP theory, or by the interest rates differential as suggested by the UIP. On the whole, the two parity conditions have individually produced mixed empirical results.

The theoretical motivation for the PPP is based on the assumption that internationally produced goods serve as perfect substitutes for domestic goods in such a manner that a backward adjustment mechanism due to the price differentials is established. The empirical verification of this hypothesis has generally been very poor (Dornbusch, 1989). A number of reasons have been cited for this, such as the relative importance of the tradable and non-tradable sectors between the countries and technology differentials, which imply that if the PPP mechanism functions at all, it must only be in a long-run perspective.

The UIP condition, which functions in the capital market, postulates that the interest rate differential between two countries is equal to the expected change in the exchange rates. However, just like the PPP, the empirical validity of the UIP as a forward-looking market clearing mechanism in the capital market has not been influential. Among other things, this failure has been ascribed to the existence of a stationary time-dependent risk premium, learning effects and expectation errors.

A seminal work by Johansen and Juselius in 1992 attributes the failure of earlier studies and lack of empirical support for the parities to the disregard for the possible interactions between the goods markets and the capital asset markets. A consideration of the systematic relationship between the two conditions implies that omission of interest rates or price levels from cointegrating vector for PPP or UIP conditions can lead to a rejection of a long-run relationship between exchange rate, the price differential and the interest rate differentials. Undeniably a joint model of the parities enables one to proper capture the linkages between the variables. It also allows for different short-run and long-run dynamics so that the error correction terms of the PPP and the UIP ensure that the model is consistent with the two parities in a steady state. In the short run it is presupposed that the conditions describe a tendency in the markets to react toward parity, connoting that neither prices nor interest rates can diverge substantially without inducing adjustment forces that tend to restore equilibrium.

Following this development, a growing body of the empirical literature has documented support for the joint modelling of PPP and UIP. Most of them argue that since exchange rates are affected by developments in both the goods and asset markets, the two parity relationships may not be independent of each other in the long-run (see, Camarero and Tamarit, 1996; Caporale *et al*. 2001; Juselius 1995; Juselius and MacDonald, 2004; MacDonald and Marsh 1997; Miyakoshi 2004; Ozmen and Gokcan, 2004). At the same time, other arguments support that disequilibrium in one market may

have consequences on the other (see, for example, Johansen, 1992, MacDonald and Marsh, 1999; Sjoo, 1995). The joint PPP and UIP model is noted to outperform the individual parity conditions in the model (Pesaran *et al*, 2000).

Since the empirical literature provides more supportive for the joint PPP and UIP, we combine the arbitrage relations and investigate whether the behaviour of the Ghana cedi follows that line of movement. Within the multivariate cointegration and vector error correction model this study shall look at the extent to which the parity conditions hold during the examined sample period. Particularly, we shall examine the strong and weak forms of the parities, thus allowing for even more channels of interaction among the variables. One important issue worth considering is the exogeneity status of the foreign variables which can shed more light on the formation of prices, interest rates and exchange rates and possible effects of economic development in the US.

The remainder of the paper is structured as follows: Section 2 sets out the theoretical framework within which the linkages between the exchange rate, prices and interest rates are established by the joint model. The data and methodological issues are discussed in Section 3, while Section 4 presents the empirical results and analysis of the statistical tests. The last section is the conclusion.

2. Theoretical Framework

The PPP assumes that nominal exchange rates moves in such manner that an equilibrium relationship is established between the price of goods and services across countries. In relative terms, the PPP relationship can be defined by as follows:

$$e_t = p_t - p_t^* \tag{1}$$

Where e_t is the nominal exchange rate (defined as the price of U.S. dollars in Ghana cedi i.e. domestic currency per U.S. dollar). p_t and p_t^* are domestic and foreign price indices. Allowing a constant in this relation would represent a permanent deviation from absolute PPP due to productivity differentials and other factors.

At the same time, the PPP seems more of a long-run interaction than implied by equation (1) since arbitrage in the goods market may be slow. Such temporary deviations of the exchange rate from PPP could be due to factors including relative growth differentials, interest rates, speculative price movements or commodity prices. This requires that the exchange rate drifts in such a manner as to restore the relative PPP. This is expressed algebraically by:

$$\Delta e_{t+1} = p_t - p_t^* - e_t \tag{2}$$

The UIP, which relates the expected exchange rate (Δe^e) to domestic interest rates (i) and foreign interest rates (i^*). can be expressed as follows:

$$e_t = \Delta e^e + i - i^* \tag{3}$$

This condition defines that the difference between the domestic and foreign interest rate produces an expected depreciation of the exchange rate. The implication of this definition is that, if the domestic interest rate is high compared to its foreign counterpart, the domestic currency would be expected to depreciate. As a forward-looking market clearing mechanism, the UIP condition tends to be relatively fast under an efficient asset market assumption compared to the adjustment in the PPP.

As documented by Frenkel (1976). the PPP and UIP propositions establish theoretical linkages between exchange rates, interest rates and prices assuming flexible prices of goods, perfect capital mobility, and perfect substitution of domestic and foreign assets. The recent development in the literature suggests that since PPP and UIP describe theoretical partial equilibrium equations in the goods and capital markets respectively, it is reasonable to treat PPP and UIP jointly to allow for gradual convergence towards PPP, since there are more persistent deviations from PPP than deviations from UIP (Pesaran *et al.*, 2000).

Judging from equation (3). deviations from long-run PPP become increasingly important in the formation of expectations, as the forecast horizon grows, thereby providing a link between the capital and the goods markets. This yields an expected exchange rate defined by the price differential as follows:

$$\Delta e^e = p_t - p_t^* \tag{4}$$

Following this, we base our empirical investigation on the combined PPP and UIP conditions and model the nominal exchange rate as:

$$e_t = p_t - p_t^* - i_t + i_t^* \tag{5}$$

A necessary condition for this equation to make sense is that the interest rate differential and PPP conditions are either stationary process [$i_t - i_t^* \sim I(0)$ and $p_t - p_t^* - e_t \sim I(0)$] or that if the processes are non-stationary [$i_t - i_t^* \sim I(1)$

and $p_t - p_t^* - e_t \sim I(1)$] their combination as implied by (5) produces a stationary process $[e_t - p_t + p_t^* + i_t - i_t^* \sim I(0)]$. Denoting the real exchange rate by q_t, the above equation can be reformulated as:

$$q_t = e_t - p_t + p_t^* + \frac{1}{\theta} i_t - \frac{1}{\theta} i_t^* \tag{6}$$

In this case, the speed of adjustment to changes in the interest differential is denoted by θ. This condition for exchange rate determination assumes a long-run interaction of the price level and interest rate differentials as proposed by Dornbusch (1976)**.**

3. Data and Methodology

The study seeks to investigate the behaviour of the exchange rate based on an empirical model which supposes that the joint long-run PPP and UIP conditions hold. We consider a model formulation that does not directly impose any of the two conditions but, assumes that a tendency in the goods and asset markets adjusts to deviations from their equilibrium relationships. The Johansen (1991) cointegration test employed in the study is considered more powerful than the Engle-Granger approach (Engle and Granger, 1987; Granger, 1988). Again, the technique clarifies the number of cointegration relationships between the variables, and also allows each of the variables in the model to be used as dependent variable while maintaining the same cointegration results. However, as pointed out by Cheung and Lai (1993). the Johansen's approach does suffer from small sample bias.

Considering a well-defined five-dimensional vector $Y_t = [e, i, i^*, p, p^*]_t^{'}$ we can examine the long run relationships by using the cointegration test based on the maximum likelihood estimates from the following VAR specification:

$$\Delta Y_t = \Gamma_1 \Delta Y_{t-1} + ... + \Gamma_{k-1} \Delta Y_{t-k+1} + \Pi Y_{t-k} + \gamma D_t + \mu_t + \varepsilon_t \tag{7}$$

where $Y_t = (e_t, p_t, p_t^*, i_t, i_t^*)$ is a (p, 1) vector of observations at time t, D_t = a (p, 3) matrix of dummy variables, Γ_i = a (p, p) matrix of short-run dynamic coefficients, ε_t = a (p, 1) vector of error terms, and Π = a (p, p) matrix of long-run dynamic coefficients. It is defined as $\Pi = \alpha\beta^{'}$, where α contains the coefficients for the speed of adjustment in each of the p equations, while β contains the coefficients of the r (p, 1) cointegrating vectors. The rank of Π can be determined by calculating the p eigenvalues according to the Johansen trace and maximum eigenvalue tests.

We analyse monthly data for nominal exchange rate (expressed in units of national currency per unit U.S. dollar). domestic and foreign price levels and interest rates for the period 1997:1 to 2007:12. We have chosen this period because it covers the most recent exchange rate regime following the financial liberalization in Ghana. We use data from the International Financial Statistics (IFS) database published by the International Monetary Fund (IMF). They are expressed in logarithm forms, therefore, the estimated parameters of their coefficients measure elasticity.

The descriptive statistics of the data summarized in Table 1 indicate that the levels exchange rate has the lowest mean and median. The standard deviation shows a lower variance of 0.11 for the foreign price level, while a greater variation comes from the foreign interest rate. With the exception of the foreign prices, the levels of all the variables are negatively skewed and are characterized by a relatively low positive kurtosis. This leads to rejection of the null hypothesis of normality by the Jarque-Bera test. The first differences of the series exhibit much lower variances ranging from 0.01 to 0.05. Exchange rate and domestic prices are positively skewed distributions, with excess kurtosis. Consequently, the Jarque-Bera statistics indicates that the assumption of normality is violated due to excess kurtosis.

4. Empirical Results and Analysis

4.1. Unit Root and Stationarity Tests

The actual cointegration analysis begins with the verification of the integration consistency of the variables by using conventional unit root and stationarity tests. We employ the PP and KPSS tests to determine the number of times the variables need to be differenced to become stationary. The PP unit root test results in Table 2 indicate that the test statistics for all the variables in levels are greater than the critical values, indicating failure to reject the null of unit root. Including a constant and trend does not change the results for all the variables. The estimated statistics for the first difference of the variables leads to the rejection of the null hypothesis of unit root. These imply that, considering the 1% significant level, the PP test supports that the data generating process of the variables are integrated of order 1, [I (1)].

According to Table 2, the KPSS which tests the null of stationarity indicates that the variables are not mean-reverting (non-stationary) in the levels as the estimated test statistics for all the variables are greater than the critical values at the 5% significant level. Of particular interest is the evidence that i* is stationary at the 10% level. This means that the variables are I (1). providing a consistent set of first difference stationary Gaussian process for the proposed model.

4.2. Long-Run Relationships

According to the PP and KPSS tests all the variables are integrated of order 1, so we proceed to test if there is a long-run relationship between the variables. The methodology employed is the Johansen (1991) multivariate Full

Information Maximum Likelihood (FIML) cointegration test. Since the Johansen cointegration test and the behaviour of the residuals are sensitive to the lag order we first consider the optimal lag length for the model specification. The Akaike, Schwarz, and Hannan-Quinn information criteria provide different orders for the model, which requires particular attention to residual autocorrelation and heteroskedasticity. While the FPE and AIC support lag length of 5, the SIC and HQC opt 2. We follow the SIC and HQC and use 2 lags as they give residuals that are reasonably well-behaved and theory-consistent.

In order to identify the cointegrating relations, we apply the Johansen cointegration technique to the pentavariate model which includes both the PPP and UIP conditions by assuming an intercept and trend in the cointegrating equation. The estimated trace and maximum eigenvalue statistics reported in Table 3 support one long-run relationship between the variables at the 0.05 level. This also suggests that the system is stationary in one direction in which the variables have an error correction representation with error correction terms incorporated into the equations indicate the speed of convergence and the presence of causality (Engle and Granger, 1987; Granger, 1988). The evidence suggests that price and interest rate differentials play significant roles in the modelling of exchange rates in Ghana such that movements in the cedi can better be controlled by interest rate movements and price stability. Table 3a displays the unrestricted cointegrating vectors. When normalized on the nominal exchange rate, the vector has signs consistent with the theory of combined PPP and UIP (see Table 3). The relationship corresponds to (1.00, -6.08, 2.26, 0.23, -0.31).

Considering the magnitudes of the coefficients, we find that in the long-run, the nominal exchange rate is more responsive to domestic price levels than their foreign counterpart. Interestingly, however, the exchange rate seems more responsive to the foreign interest rate dynamics/movements than the domestic rates. The misspecification and diagnostic tests reported in Table 4 reveal that the model is well-behaved in terms of residual serial autocorrelation and heteroskedasticity. However, we disregard the violation of multivariate normality caused by excess kurtosis since the cointegration estimates have been argued to provide robust results (Gonzalo, 1994).

4.3. Hypothesis Testing

We proceed by testing the validity of the combined PPP and UIP restrictions through likelihood ratio tests developed by Johansen and Juselius (1992). The restricted cointegrating relations will be estimated accordingly to test how consistent it is with the theoretical restrictions postulated by equation (6). If we find that the combined PPP and UIP is significant, then we can impose the restriction in the exchange rate model. In the event that the strict form is rejected, we can examine less restrictive alternatives. Table 5 reports the LR test results.

The strict forms of the PPP and UIP are tested by imposing the following restrictions among the variables of the cointegrating vectors: [$\beta_1 = -\beta_2 = \beta_3 = 1$, $\beta_4 = \beta_5 = 0$] and [$\beta_1 = \beta_2 = \beta_3 = 0$, $\beta_4 = -\beta_5 = -1$]. Under this assumption, the test statistics distributed as X^2 (4) yields the values 36.3 and 35.2, which reject the strict forms of PPP and UIP respectively. This indicates that none of the two conditions is itself a stationary process. That is, combinations of the restricted variables do not produce any stationary process. Further tests of the combined strict-form PPP and strict-form UIP gives $X^2(4) = 35.7$ and a p-value is 0.00. This rejects the null hypothesis that both price and interest rate differentials affect the exchange rate proportionally/symmetrically.

Since the strict-forms of the parity conditions are rejected, we explore the weak forms of PPP and UIP. We formulate the hypothesis as $\beta_4 = \beta_5 = 0$ (for weak form PPP) and $\beta_1 = \beta_2 = \beta_3 = 0$ (for weak form UIP). The p-values, 0.01 for $X^2(3)$ and 0.00 for $X^2(2)$. reject the weak forms of the parity conditions. Notably, under each of the restrictions, the signs of the coefficients of the eigenvectors are not consistent with the PPP and UIP.

Following this, we consider if a combination of the strict form of one and the weak form of the other hold. We express the hypothesis of strict form PPP and weak form UIP by imposing restrictions on the first three elements as [$\beta_1 = -\beta_2 = \beta_3$] and leave the interest rate variables unrestricted. It postulates that price differentials affect the exchange rate proportionally while interest rates affect it in a non-symmetrical manner. The p-value rejects the null hypothesis. The signs of the unrestricted interest rate variable are not consistent with the UIP condition. The weak form PPP and strict form UIP is formulated as [$\beta_4 = -\beta_5$]. Here, we hypothesise the interest differential affects the exchange rate proportionally while prices affect it non-symmetrically. The estimated p-value rejects the null hypothesis. In this case, the LR test statistics distributed as $X^2(1)$ with p-value 0.82 fails to reject the null hypothesis. The signs of the coefficients of the eigenvectors are consistent with the PPP condition.

Again, a test is conducted to find whether the price differential or nominal interest differential enters the equilibrium relation by imposing a restriction that $\beta_2 = -\beta_3$ and $\beta_4 = -\beta_5$ respectively. The former assumes that relative price movements affect the exchange rate symmetrically no matter where they initiate, but not proportionally. The LR test statistic indicate that the null hypothesis that only the price differential enters the cointegrating relation is rejected while a p-value of 0.82 fails to reject the null that only the interest rate differential enters the long-run relation. We note with

particular interest that, in the latter, the signs for the exchange rate, domestic and foreign prices are consistent with the PPP condition.

Just like in the case of the weak form restrictions, we test proportionality and symmetric restrictions expressed as $\beta_2 = \beta_3$ and $\beta_4 = \beta_5$. This test hypothesizes that prices and interest rates affect the exchange rate irrespective of where they originate. While the PPP symmetry is rejected, the test fails to reject the null of the UIP symmetry. The coefficients of the first three variables retain their signs consistent with the PPP condition.

4.4. Speed of Adjustment and Long-Run Weak Exogeneity

Considering the deviations from the PPP and UIP conditions explained above, an important issue worth addressing is how fast the variables revert to the long run equilibrium relationship. Table 6 illustrates the speed of adjustment parameters. The sign and magnitude of these convergence parameters give information about the direction and speed of adjustment towards the long-run equilibrium course. We find that the adjustment coefficients of the nominal exchange rate, domestic prices and interest rates are statistically significant in the short-run mechanics of the process. The percentage of the total adjustment offset in each successive month is 2.8%, 3.8% and 4.6% for exchange rate, domestic prices and interest rates respectively. This shows that the adjustment process lies between 1.75 and 3 years for the system to restore the long-run relationship.

In this section we employ the Likelihood Ratio test developed by Johansen (1991) for restrictions on the matrix loading factors. We formulate the long run weak exogeneity test as a zero row in the loading factor, α and the null hypothesis that the variable is weakly exogenous. If no evidence is found against the null hypothesis, the variable would be said to push the system without being influenced, and thus can be considered as a driving force in the system.

Table 7 below presents the LR test results of weak exogeneity for the system (Johansen and Juselius, 1990). Foreign prices and interest rates are found to be weakly exogenous indicating that none of the cointegrating vectors enters the foreign equations. The weak exogeneity of the foreign interest rate is not a surprising result considering that US financial shocks are usually believed to disturb international capital markets. A joint test for weak exogeneity of the foreign variables gives a p-value of 0.80 suggesting that, a shock in the foreign variables cause the PPP and UIP to deviate from the equilibrium relationships, but they do not adjust to restore the condition. One can argue that, the US prices and interest rates are not affected by the equilibrium relations; though, the rest of the variables move so as to establish the equilibrium relations. This result confirms that the cedi/U.S. dollar exchange rate, the domestic prices and interest rates are affected by developments in the foreign variables. The exchange rate can therefore be said to be a channel through which U.S. monetary policy is transmitted to the Ghanaian economy.

5. Conclusion

The paper has explored exchange rate modeling in Ghana by considering the interactions between the goods and capital asset markets using monthly data spanning from 1997:1 to 2007:12. The analysis was done by following the cointegration and VEC methodology to define the long-run stationary relationships as well as common stochastic trends. The vector variables considered were nominal cedi/US dollar exchange rate, consumer price index for Ghana and the US, short term interest rates for Ghana and the US.

The results show that the variables are integrated of the first degree but form a stationary process when combined linearly, which provides evidence that there exists a steady-state relationship between them. The cointegration vector shows signs that are consistent with the joint validity of the unrestricted PPP and UIP conditions. Based on the likelihood ratio test we find that the stationarity hypothesis of the strict form PPP and UIP conditions are strongly rejected. Also, the strict form UIP holds when the weak form PPP is allowed in which case the symmetric and proportionarity conditions of the UIP are not rejected. This implies that the nominal exchange rate is defined when the interest differential is allowed to affect it proportionally while prices affect it non-symmetrically.

The weak exogeneity tests reveal that significant causality runs from the foreign variables to the Ghana cedi exchange rate and domestic variables. Further we find that in case of deviations from the equilibrium relationship are offset by adjustments in the nominal exchange rate and the domestic variables such that a percentage of the total adjustment required is accomplished in each successive month. Since the foreign variables serve as the driving force of the system, they do not take part in the adjustment process. The findings suggest that the interactions between the goods and capital assets markets matter for the conduct of monetary policy and exchange rate dynamics in Ghana.

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Table 1. Descriptive Statistics

	e	p	p^*	i	i^*
Levels of variables					
Mean	-0.54	4.98	4.66	3.12	1.28
Median	-0.21	5.03	4.62	3.25	1.61
Std. Dev.	0.58	0.55	0.11	0.52	0.59
Skewness	-0.87	-0.21	0.68	-0.42	-0.83
Kurtosis	1.98	1.62	2.10	1.87	2.12
Jarque-Bera	22.4	11.3	14.6	10.9	19.4
Probability	0.00	0.00	0.00	0.00	0.00
First difference of variables					
Mean	0.01	0.01	0.00	-0.01	-0.00
Median	0.00	0.01	0.00	0.00	0.00
Std. Dev.	0.02	0.01	0.01	0.05	0.05
Skewness	2.93	2.12	-0.20	-1.12	-1.02
Kurtosis	12.2	16.2	4.11	8.06	6.78
Jarque-Bera	654	105	7.75	167	101
Probability	0.00	0.00	0.02	0.00	0.00

Table 2. Unit Root and Stationarity Tests

	levels		difference	
Variable	Constant	Constant and trend	Constant	Constant and trend
Phillips-Perron (PP) Test				
e	-2.14	-0.96	-5.91***	-6.47***
p	-1.26	-1.26	-6.30***	-6.32***
p^*	1.49	-1.95	-9.93***	-10.2***
i	-0.70	-2.06	-7.19***	-7.16***
i^*	-1.21	-0.92	-5.23***	-5.23***
Kwiatkowski, Phillips, Schmidt and Shin (KPSS) Test				
e	1.19**	0.31**	0.33	0.07
p	1.41**	0.25**	0.18	0.05
p^*	1.27**	0.28**	0.42	0.05
i	1.18**	0.22**	0.07	0.05
i^*	0.38**	0.25**	0.25	0.09

The critical values for the PP at 10%, 5% and 1% significance level are –1.61, -1.94 and -2.57. ***, **, * denotes the rejection of the null at 10%, 5% and 1% significance levels. The critical values for a test with a constant and trend are -3.14, -3.44 and -4.03, respectively. The critical values for the KPSS test with a constant are 0.11, 0.14 and 0.21 at the 10%, 5% and 1% significance level, respectively. For a constant and trend the critical values are 0.34, 0.46 and 0.73, respectively. ***, **, * denotes the rejection of the null at 10%, 5% and 1% significance levels.

Table 3. Cointegrating Coefficients

	e	p	p^*	i	i^*
Unrestricted cointegrating coefficients					
β_1	6.19	-37.6	14.0	1.44	-1.94
β_2	4.76	-6.03	33.3	-7.75	-2.70
β_3	-1.11	-0.72	-31.0	0.35	0.77
β_4	6.05	3.46	20.6	-2.65	0.18
β_5	-3.43	-11.1	19.0	5.51	-3.13
Normalized cointegrating vector					
Coefficient	1.00	-6.08	2.26	0.23	-0.31
Standard error		(0.82)	(1.06)	(0.18)	(0.10)
Test statistics		[-7.37]	[2.12]	[1.26]	[-3.12]

Table 4. Misspecification and Diagnostic Tests

Test	X^2 (df)	p-value
Autocorrelation LM (1)	30.7(25)	0.19
Autocorrelation LM (4)	22.6(25)	0.59
Normality	3637(105)	0.00
Portmanteau Tests for Autocorr.(4)	72.1(50)	0.02
Portmanteau Tests for Autocorr.(6)	110(100)	0.22
Heteroskedasticity tests: No Cross Terms	358(330)	0.13
Heteroskedasticity tests: With Cross Terms	1217(1155)	0.09

Table 5. Restricted Cointegrating Relation

Hypothesis	e	p	p^*	i	i^*	X^2	p-value
Individual parity conditions							
Strict PPP	1	-1	1	0	0	36.3(4)	0.00
Strict UIP	0	0	0	1	-1	35.2(4)	0.00
Weak form PPP	5.99	-24.9	-1.22	0	0	8.40(3)	0.01
Weak form UIP	0	0	0	0.98	0.27	26.2(2)	0.00
Combined parity conditions							
Strict form PPP and strict form UIP	1	-1	1	1	-1	35.7(4)	0.00
Strict form PPP and weak form UIP	1	-1	1	-3.35	-0.71	26.0(2)	0.00
Weak form PPP and strict form UIP	3.20	-20.3	6.80	1	-1	0.04(1)	0.82
Proportionality and symmetry conditions							
$\beta_2 = -\beta_3$	7.41	-32.1	32.1	-1.54	-2.70	5.96(1)	0.01
$\beta_4 = -\beta_5$	5.90	-37.4	12.5	1.83	-1.83	0.04(1)	0.82
PPP symmetry $\beta_2 = \beta_3$	1.08	-17.3	-17.3	4.05	0.68	11.9(1)	0.00
UIP symmetry $\beta_4 = \beta_5$	7.88	-33.0	17.5	-1.81	-1.81	3.35(1)	0.06
Joint symmetry for PPP and UIP	3.32	-15.5	-15.5	0.86	0.86	15.9(2)	0.00

Table 6. Adjustment Coefficients

	e	p	p^*	i	i^*
Coefficient	0.03	0.04	-0.00	0.05	-0.02
Standard error	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)
Test statistics	[2.87]	[5.63]	[-0.21]	[1.76]	[-0.78]

Table 7. Long-run Weak Exogeneity Tests

Hypothesis	e	p	p^*	i	$i*$	X^2	p-value
$\alpha(3,1) = 0$	6.19	-37.6	13.6	1.41	-1.93	0.03(1)	0.84
$\alpha(5,1) = 0$	6.43	-38.1	16.5	0.90	-2.18	0.40(1)	0.52
$\alpha(3,1) = \alpha(5,1) = 0$	6.42	-38.1	16.1	-2.17	0.89	0.42(2)	0.80