One approach to resolve the exchange rate puzzle: results using data from the United Kingdom and the United States

Ariff, M. & Zarei, A.

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One Approach to Resolve the Exchange Rate Puzzle: Results using data from the United Kingdom and the United States

Abstract

We approach a significant research topic in international economics by restating the test procedures in a novel manner consistent with monetary theorems with controls using monetary variables and applying an appropriate econometric methodology to re-examine three aspects of exchange rate behavior. (i) Does the inflation (price) factor affect nominal exchange rate; (ii) Do relative interest rates between countries affect a country's exchange rate; and (iii) Do the *price and interest rate effects* hold if controls for non-parity factors are embedded in tests? The data series for this study are taken over 55 years covering pre-and-post-Bretton-Woods era: a second test was done over the post-Bretton-Woods period only using 30 years of data. Also, the traditional factors of parity conditions are extended in this research to take into account recently theorized and tested non-parity factors related to cash flows. The resulting evidence affirms clearly that both the parity factors (prices and interest rates) and the non-parity factors affect exchange rates significantly over the long run, also over the 30-year period. In our view, these findings extend our knowledge of how currency behavior is consistent with parity *and* non-parity theorems.

Keywords: Exchange rate, Non-parity factors, Prices, interest rates, Panel cointegration, Dynamic OLS

JEL Classification: F23, F31, G12

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1. Introduction

Bahmani-Oskooee *et al.*(2009) dubbed the lack of support for parity theorems as an unsolved "puzzle". Hence, this research is motivated to explore why there is a lack of support especially for the purchasing power parity (PPP) by revisiting the parity theorem research literature and applying in our research more appropriate and powerful econometric tests. We report findings in this study by providing quite strong supporting evidence consistent with both the PPP and the International Fisher Effect (IFE) as to their influences on the exchange rates of the United States (US) and the United Kingdom (UK) over a long period pre- and post-Bretton Woods. Both prices and relative interest rates have been shown to have significant effects on the nominal exchange rates, which we view as a strong support for the parity theorems: there is only a week support for purchasing power parity.

The focus of this paper is therefore on two major theories on exchange rate determination: Cassel (1918) for PPP and Fisher (1930) for IFE. Despite the fact that these theories have been applied in most studies as well as in practical policy decisions in a variety of contexts, there is still no unanimity on the theory-predicted results. (i) Does PPP factor affect exchange rate; (ii) Does IFE affect exchange rate; and (iii) Do PPP and IFE hold if controls for already-known non-parity factors are embedded in our tests? The data series for this study are taken over a 55-year period. Also, to the traditional factors of parity conditions, we add the recently theorized and tested non-parity factors in this research.

Several other theories that exist in international economics from monetary side of economics predict how exchange rates are determined, although, to-date, there is scant support in almost all studies for the prediction that relative prices have a statistically significant effect even in the long run, let alone short run. This then calls for a novel approach to re-examine the exchange rate pricing behavior in the two most popular currencies using a long-length time series with more up-to-date and appropriate econometric approach. This paper explains the new approach, the appropriate models and the resulting findings.

The rest of the paper is organized into five sections. The next section is a very brief statement of the theories on exchange rate behavior from the vast literature on this topic. The third section provides a quick summary of empirical literature that appears to suggest that there is lack of evidence to support the PPP theory predictions. The data sources and tests are explained in the fourth section. The findings are reported in the fifth section as two tests using a full-length data and a short period of 30 years data and the paper ends with a summary in section 6.

2. A Review of Exchange Rate Literature

Existing studies suggest large variations in several currency exchange rates under the free-floating system, which started in earnest in 1973, after the breakdown of the Bretton Woods monetary arrangement. Researchers have begun to re-examine the exchange rate behavior again especially after the Global Financial Crisis (GFC) in 2008-9, after which the currency trading volume has jumped almost 60 per cent (up to $4 trillion in 2010, and $5.3 trillion in 2013)[1]. There is fresh interest on both theoretical and empirical studies of exchange rate determination. Under the monetarist approach of exchange rate determination, the PPP and IFE are assumed to fully explain how currency exchange rates are determined whereas the prior literature by failing to uphold the theorems led to the issue being labelled a "puzzle". We aim to show that with proper

[1] Information is obtained from the survey of Triennial Central Bank as of April 2013.

transformation of variables and applied econometrics, the two-factor in parity theorems can fully explain exchange rate changes. Recent researchers have added few non-parity factors (Ho & Ariff, 2012) to the two parity factors from monetary theories. In so doing we will also try using a multi-factor model (in conformity with a strand of literature) to see if that model is as good as the simple parity-alone model.

Scant evidence is available that the PPP holds in the short-run although, using a novel approach, one study (Manzur *et al.*, 1995) provides support for a long-run equilibrium only. There is ample literature supporting IFE on the exchange rate (Edison *et al.*, 1999). Hence, the literature relevant to this study is from studies on inflation and interest rate differences *as well as* known non-parity factors. Our review of literature is limited to these factors.

2.1 Purchasing Power Parity

The PPP suggests that the exchange rate is periodically affected by the relative price differences in traded goods/services across any two trading partner countries (Cassel, 1918). PPP is often said to have originated in Spanish literature on inflation during the periods of gold importation from the New World. It examines the relationship between the exchange rates across different countries. It asserts that inflation, measured as price differentials across any two trading countries, should be offset by exchange rate changes. Hence, any two identical goods produced in any two countries are said to have a similar base price, as stated by the law of one price for the same basket of goods traded across two economies with different currencies.

Scholars in international finance and macroeconomics have found PPP's potential for a wide range of applications especially in the post-Bretton Woods era. It also provides a basis for international comparison of income and expenditure under an equilibrium condition, given an efficient arbitrage in goods traded. Most importantly, it is a theory for short-run as well as long-run exchange rate determination (Ho & Ariff, 2012), whereby the authorities would set or steer a nominal exchange rate that satisfies international competition.

The relative version of PPP states that a country's currency will be adjusted based on the ratio of the rate of inflation and its trading partner's inflation rate. Subject to periodic fluctuations of real exchange rates, there is a possibility for the relative PPP to hold in the long run but not the short run. This study uses the relative version of PPP as in the following equation:

$$\ln E_{jt} = a_j + b_j ln\left(\frac{P_t^d}{P_t^f}\right)_{jt} + \mu_{jt} \quad (1)$$

where, E is the Exchange rate of country j over time period t, P^d is the Domestic prices, and P^f *is* Foreign prices.

2.2 International Fisher Effect

A linkage between interest rate and inflation is postulated in a so called *theory of interest* (Fisher (1930) which predicts that the nominal interest rate is equal to the summation of real interest and expected inflation rates dubbed the Domestic Fisher Effect. There is a further prediction that such a behavior would also lead to the interest rate differences between any two nations would be met by a corresponding change in the nominal exchange rate. The relationship between interest rates and inflation is one to one, assuming a world of perfect capital mobility with no transaction costs involved. Furthermore, the real interest rate is assumed to be unrelated to the expected inflation with its value determined solely by real economic factors such as capital productivity and investor time preference. This hypothesis plays a crucial role, given the fact that, subject to the correlation between real interest rate and inflation, the nominal interest rate will not be fully adjusted after a change in the expected inflation. A large number of studies have been conducted on the IFE theory. The early studies go back to the 1980s. There is still evidence of several mixed results concerned the IFE theorem.

As a general rule, the law of one price in the PPP holds when there is equilibrium in foreign exchange markets, whereby deposits of all currencies possess an identical rate of return. Any change in a country's interest rate will create disequilibrium in its currency requiring long-term adjustments of the other country's exchange rate to restore the new equilibrium. In other words, the ratio of changes in exchange rates is determined by the ratio of domestic to foreign interest rate (relative interest rate) as shown in the following equation:

$$\frac{E_{t+1}}{Et} = \left(\frac{1+i_t^d}{1+i_t^f}\right) \quad (2)$$

where i^d is the domestic interest rate, i^f represents foreign interest rate, and E is defined as in Eq. (1).

Accordingly, the IFE states that the interest rate differences across countries are unbiased predictors of any future changes in the spot nominal exchange rates. Tests on this theorem suggest that the interest rate differences are correlated significantly with exchange rate changes, although most tests show that, due to under-specification of the relationship, the explained variation is very low as shown by low R-squared values. Hence, there is also a need to re-examine if such test results are due to simpler methodology used in prior research.

2.3 Non-Parity Factors

There have been several important studies exploring if one or more non-parity factors are also relevant for exchange rate movements, given the lack of explanatory power of the monetary theorems with two parity conditions. Several other such factors are tested in another study, Ho and Ariff op cit., identifying few key non-parity factors as being relevant to theory-building on exchange rates. Hence, this study incorporates some non-parity factors as control variables in the tests of parity theorems. Thus, we believe that the introduction of a fully-specified model would lead to robust results on exchange rate behaviour compared to the existing US studies limited to the parity factors only. Hence, the resulting findings may provide fresh insights on the very old issue of parity factors.

3. Empirical Evidence on Parity Theories

3.1 Purchasing Power Parity

Because the nominal prices are unstable or may be sticky and the nominal exchange rates are subject to wide fluctuations as the result of volatilities in flows of capitals, goods and services, the short-run equilibrium is often explained as not likely to hold. However, several empirical concerns have risen about this position of the literature. For example, if interest rates, which are also subjected to other effects, are holding in short-run, why is there lack of evidence for similar behavior for inflation? The mixed evidence on PPP equilibrium can be attributed to the modeling of exchange rate determination and sources of disturbances to real exchange rate.

The basic empirical studies on PPP before the 1980s are mostly concerned about the tests of absolute PPP with results rejecting the PPP hypothesis. The most influential study of this type (Frenkel, 1976) obtained estimates of respective coefficients that would not suggest a rejection of the null hypothesis, even considering that the sampled countries in the study are among high inflation economies.

A large number of studies in the late 1970s failed to validate a significant PPP relationship, mainly due to the non-stationarity nature of the residuals, as we have come to discover since the 1980s. In particular, while these studies failed to confirm the unit root or the stationarity property of the residuals, the relationship between the respective variables (nominal exchange rates and relative prices) was mismeasured resulting in spurious regression parameters. Accordingly, in the early1980s, researches began to test for stationarity using newly developed unit root tests known as Dickey-Fuller's ADF test (Dickey *et al.*, 1981). The ADF test despite its revolutionary move, still failed to strongly support the presence of significant PPP in nearly all studies of unit root tests using cross country data for the free floating period, except only a few evidences of long run PPP behavior, given that the real exchange rate deviations from its mean value are only temporary in nature. Such a failure was basically attributed to the limited power of the tests employed, especially in small samples using the simulation exercises (Levin *et al.*, 1992).

Towards the late 1980s, researchers attempted to overcome the problem of low power by taking advantage of long horizon time spans of data. By using an error-correction model (Edison, 1987), researchers analyzed the dollar-Pound sterling data over a long period and found slightly higher degree of significance for the PPP. Consistent with this study, a large number of other studies in the early 1990s attempted to test for PPP reliability over longer time horizons (something we do in this study) while using a number of new and sophisticated methods such as cointegration, variance rations, fractional integration as well as error correction models. The results of these studies favored the PPP predictions: these also supported the real exchange rate mean-reverting behavior (Rogoff, 1996). Mollick (1999) uses data for Brazil and analyzed long time period data over 1885 to 1990. The results, however, were mixed: the unit root hypothesis was not rejected by the formal unit root tests, while, the trends of time series favored a stationarity of the variables.

Autoregressive processes used in the model yielded robust and satisfactory estimation of the real exchange rate compared with regression methods.

Consistently, Lothian *et al.* (1996) applied the annual real exchange rate data of franc-sterling and dollar-sterling for a total of two centuries. The results for such a long time period were satisfactory by rejecting the null hypothesis of unit root test using both ADF and Phillips-Perron (PP) test (Phillips *et al.*, 1988). Also, in a separate study, Lothian *et al.* (2000) supported their belief about the PPP reliability over long run and a method of faster estimation of mean reversion speed for the real exchange rate. Andersson *et al.* (1999) came out with a panel unit root test, through which the null hypothesis of no co-integrating relationship between the domestic and foreign price levels was rejected for some of the sampled countries. Using a relatively similar small sample as the one applied by Andersson & Lyhagen (1999) with long time horizon for real exchange rate data of 21 countries, Shively (2001) found evidence of consistent PPP relationship to add up another satisfactory result for longer time periods.

Concerning the results obtained for the holding of PPP, after three decades of floating exchange rates, there is still evidence in various studies in that the strong prediction of PPP is not borne out in tests.

3.2 International Fisher Effect

The relationship between real interest and real exchange rates is highlighted in several studies using post-Bretton Wood data. One primary and yet well-known model of exchange rate is *the sticky price model* of Dornbusch (1976) which suggests that, under a flexible exchange rate framework, prices of goods in a country are subject to slower (stickier) adjustments than those of capital assets, thus initiating arbitrage opportunities in the short-run, as suggested by the IFE (see Manzur & Ariff, 1995 identifying the time periods for stickiness).

Apart from the models, there is evidence of several important studies on the correlation of real interest and exchange rates with several different assumptions. Mishkin (1984) considered the equality of real interest rates across a sample of major economies unlike the finance theory which indicates that risk premium for comparable securities in different currencies of denomination may differ from each other's. Likewise, Mark (1985) tested for the conditions of high capital mobility and equality of short term *ex ante* real interest rates and net of tax real rates among flexible and specific market-linked exchange rates. The results are consistent with those of Mishkin in that the IFE hypothesis of parity conditions was rejected considering its joint relationship with the *ex-ante* PPP.

Large number of critics made obvious conclusions that there is lack of support for some of the theories concerned with the test validity and with a view that the cointegration of real returns are not tested in Mark & Mishkin's study. Other studies tried to control for the drawback by introducing tests of cointegration. Notably, the two-step method of Engle-Granger test of co-integration was applied in several preliminary studies in the late 1980s and in the early 1990s in order to examine how the real exchange rates are cointegrated with real interest rates (Meese *et al.*, 1988; Edison *et al.*, 1993; Throop, 1993). After applying the maximum likelihood estimation method for the Johansen co-integration test, the results became somewhat more favorable to support the theory (Johansen *et al.*, 1992; Edison & Melick, 1999).

Similar to the PPP, there is evidence in several empirical studies that long-run relationship between exchange rate and interest rate changes appears to hold well (Hill, 2004). On the other hand, in the short-run, the IFE has not been proven to hold (Cumby *et al.*, 1981). Such mixed evidence motivated us to reconsider the re-testing also for IFE.

3.3 Non-parity Factors

While these theories are generally treated as general equilibrium conditions - known as parity theorems - researchers have recently identified a number of other-than parity factors, as also influencing the exchange rates. Given the lack of strong evidence for full explanatory power of parity factors as determinants of exchange rate behavior, these so-called 'non-parity' factors are gaining significant popularity in recent years in exchange rate studies.

The level of international reserves of a country is one of the significant determinants of exchange rates (Frankel *et al.*, 1996): this comes from the Philip's Curve effect long observed in international economics studies. A country's currency is subject to movements as a result of unexpected changes in foreign reserves held by the central authority to service the trade bills arising from international trade and also to defend currency during crisis periods. Hence, there is a direct relationship between the currency value and any sort of unexpected changes in the country's reserve or even the level of foreign currency debt. The relationship between level of international reserve and currency value has been tested by a number of scholars (Martínez, 1999; Marini *et al.*, 2003). They show a significant association between the respective variables.

Cash flows arising from the trade and capital account balances have been shown to have significant effects on exchange rate changes. Thus, these two variables are legitimate as control variables in addition to the others already considered. There are several more variables which are not strictly falling into cash flow type variables consistent with the monetary economics, so we leave out these variables to build a simple model. For example, for currencies affected by the 1997/8 Asian financial crisis, the reversal of capital flows, and the resulting current account deficits have been shown as common non-parity factors in that crisis. Therefore these variables should have tremendous impacts on exchange rates. This strand of literature also points out significant explanatory role of current account balances in the determination of exchange rates across several major economies (Dornbusch *et al.*, 1980; Engel *et al.*, 1985; Karfakis *et al.*, 1995).

The level of capital flows also plays a crucial role in determining the behavior of exchange rates. The accessibility to cash from capital markets has become easier because of new rules and regulations and general reduction of capital controls, leading to improved globalization of cash flows. This is partly relevant to exchange rates, given the freedom in global flows of capital. There are several studies that have identified significant relationship between the level of capital flows and exchange rates changes. Examples are the studies of Kim (2000), Calvo *et al.* (2003), and Rivera-Batiz *et al.* (2001).

4. Research Design, Variables and Modeling

This research is designed to investigate whether a relationship between exchange rates and parity variables exist, with and without controls for non-parity variables specified in our test models. The data series on variables (exchange rate; inflation; interest rate differences; non-parity factors) are from the US and the UK. We use a long period starting from the post-floating era starting in 1985 to 2014, with 120 quarterly data.

The test model is developed specifying inflation and interest rate difference as parity factors on the right-hand side, and then control variables, which are non-parity factors. In such a full model, a single regression could suffice for tests on estimating the effects of parity and non-parity factors.

The tests are run one for a full 55-year period covering the pre-and-post-Bretton-woods era; the other test is over a shorter span of 30 years in the post-Bretton Woods era. This is equivalent to verify if the shorter period and the longer period results are dissimilar or similar.

We believe that this approach could yield new insights on (i) how exchange rates behave differently in presence of inflation and interest rate changes; (ii) the validity of non-parity factors for the US$ (USD) and British pound (GBP) exchange rates. During the test periods, both USD and GBP played significant roles as international currencies. Hence, the tests are done using these currencies, and data from the respective economies.

4.1 Data, Variable Transformation and Testing

Data employed in this study are Nominal Exchange Rate (NER), Consumer Price Index (CPI), short-term risk-free (Treasury) interest rates, Total Reserve, Total value of imports, Current Account Balance, GDP, Total value of exports, balance of payment, and net capital accounts. The GDP data are used to standardize other variables. The series are quarterly data over 1985-14. Table 1 provides a summary of variables, with their expected signs in tests. The major sources of data are: *The International Financial Statistics* (IFS) CD-ROM, *Thomson Reuters DataStream,* the *Capital IQ* database. The Consumer Price Index (CPI) is used as a proxy for measuring the purchasing power parity.

Table 1: Variable specification, definitions and expected signs
Table below describes the variables along with their definition and expected signs.

No.	Variables	Definition	Expected Sign

1.	LNER	Log of Nominal Exchange Rate over time periods	Dependent Variable
2.	LCPI	Log of Prices over time periods	+
3.	RIFE	(1+ Short-term Real Domestic Interest Rate) / (1+Short-term Real Foreign Interest rate)	–
4.	TRes/M	Total Reserve / Total Import	–
5.	CA/GDP	Current Account Balance / GDP	+
6.	TTrade/GDP	Total Exports and Imports / GDP	–
7.	BOP	Balance of Payments / GDP	+
8.	NCA	Current Account Balance / GDP	+

The CPI measures the prices of a basket of goods available in each country: the US and the UK. The theory of international fisher effect is measured according to short-term risk free interest rates (Treasury bills) for the US dividing by the interest rate for the UK as a measure for the foreign interest rate.

One problem we faced in the cases of the UK and the USA, the variable, Total Reserve, had undergone substantial change around some time period.[2] For additional factors included in the second period, we had data available from 1985, so the test is over the post-Bretton-Woods era.

4.2 Modeling

[2] Specifically both central banks sold part of the gold reserves in the face of financial crisis as pointed out by the reviewer. We checked this issue, and found that the series had had substantial reductions in the years suggested by the reviewer: Please see the graph in the Appendix showing that the series had substantial reductions in the time period mentioned by the reviewer. Therefore, the observations we had used already adjusted the series for the sale of gold in the total reserve.

The full model for the exchange rate is thus based on a single equation which includes a number of parity and non-parity factors. The following equation is used to test the basic relationship among the variables.

$$NER_{jt} = \gamma_1 IFE_{jt} + \gamma_2 PPP_{jt} + \gamma_3 TRESM_{jt} + \gamma_4 CAB_{jt} + \gamma_5 TTRADE_{jt} + \gamma_6 BOP_{jt} + \gamma_7 NCA_{jt} + \varepsilon_{jt} \quad (3)$$

where NER represents the Nominal Exchange Rate, i^d denotes the Real[3] Domestic Interest Rate, i^f is the Real Foreign Interest Rate, as in the Eq. (2), CPI stands for the Consumer Price Index, as in the Eq. (1), $TRESM$ denotes total reserve over import, CAB is ratio of current account balance over GDP, $TTRADE$ represents the total trade as a proxy of total trade (export and import) over GDP, BOP represents balance of payment over GDP, NCA denotes net capital assets over GDP, over time period t: j subscript refers to country-specific data for the US and the UK. As explained in the Table 1, the variables are standardized by the GDP size, where appropriate.

As a general rule, the validity of co-integrating series is determined by investigating the order of integration of the variables, which by definition, should be similar. One may note that an equilibrium long-run relationship exists between variables (say exchange rate and parity conditions) if the variables are integrated of the same order. Thus, two series are said to be co-integrated if they move in one direction over the long-run: we also apply dynamic OLS (DOLS) as the robustness test of the ordinary panel cointegration (Pedroni, 1999, 2004). The Pedroni's test

[3] The model has included a variable for inflation as the ln on CPI. Hence, using nominal relative interest rate in the test for IFE would mean that the inflation factor is again included in the second variable. To rectify this, we subtracted the expected inflation from the domestic and the foreign current nominal interest rates so that we test the IFE on the real interest rates.

has a limit to the number of multiple factors, such that we could only test for a given number of variables.

5. Findings

In this section we present the results and discuss why these results are significantly different from the published studies. The central research question is: Do relative prices *and* relative interest rates have significant impact on nominal US dollar and British pound exchange rates when non-parity factors are embedded in the models we developed? The key results on the test of model is provided for a long-length of 55 years and a shorter 30-year period covering the post-Bretton Woods free floating era.

5.1 Descriptive and Diagnostic Statistics

These statistics in Table 2 suggest that the variable means are very close to zero in most cases because of data transformation. The relative real interest rate is the ratio of two-country interest rates expressed as explained earlier.

Table 2: Descriptive Statistics of Variables Used in Test Models
Table below reports a summary of descriptive statistics on the variables used in this study.

Variables	Mean[a]	Median	SD[b]	Skew[c]	Kurt[d]	JB[e]	Observation
LNER (Dependent variable)	0.553	0.567	0.105	-0.495	3.633	12.979	226
LCPI	0.501	0.501	0.527	0.000	1.021	36.890	226
RIFE	0.00004	0.00001	0.009	0.023	2.596	1.554	226
CAGDP	-0.024	-0.023	0.015	-0.335	2.595	5.770	226
TTRADE	0.097	0.064	0.063	0.768	2.333	26.407	226
TRESM	1.146	1.002	0.476	0.538	2.353	14.868	226
BOP	0.060	0.000	0.150	0.824	3.947	34.029	226
NCA	0.001	0.000	0.001	1.046	3.543	43.995	226

Note: [a]Mean represents the average or mean value. [b]SD represents standard deviation. [c]Skew represents skewness. [d]Kurt denotes kurtosis and [e]JB stands for Jarque-Bera test.

The mean and the median LNER (nominal exchange rate) are very close (0.553 and 0.566) with a standard deviation of 0.105. The other variables too are described as shown in the table: for example, the balance of payment was 6 per cent and the net capital flow is 0.1 per cent.

5.2 Panel Unit Root and Cointegration Results

Table 3 reports the order of integration and the stationarity properties of the variables. To do those, we use two panel unit-root tests of Levin & Lin (1992) (LL) and Im *et al.* (1995) (IPS).

The panel unit-root test have robust properties compared to pure time-series test as it provides consistent estimates of the true values of parameters when both time and cross-sections tend to infinity. Based on the statistics in the table, we find most of the series are stationary at order 1. The levels data are not stationary except in the cases of total trade (TTRADE) net capital assets (NCA).

Table 3: Panel unit root Tests on the variables used in Test Models

The following table shows the statistics related to the Unit Root tests. Most variables are shown to be integrated at first order, indicating random walk behavior at level, and thereby fulfilling the requirements for relevant cointegration tests.

Variables	Deterministic Terms	LL Statistics	IPS Statistics
Levels			
LCPI	Constant, Trend	-0.611	0.252
LNER	Constant, Trend	1.081	-1.631
RIFE	Constant, Trend	3.768	-3.319***
CAGDP	Constant, Trend	0.678	0.163
TTRADE	Constant, Trend	-3.987***	-3.606***
TRESM	Constant, Trend	0.314	0.180
BOP	Constant, Trend	3.792	-1.291
NCA	Constant, Trend	-13.409***	-13.340***
First Differences			
LCPI	Constant	5.739	-2.248**
LNER	Constant	-12.212***	-12.912***
RIFE	Constant	17.206	-10.028***
CAGDP	Constant	-19.518***	-18.052***
TTRADE	Constant	-12.094***	-11.172***
TRESM	Constant	-15.437***	-14.361***
BOP	Constant	-1.564**	-17.969***
NCA	Constant	-7.825***	-14.562***

The number of lags is determined by the criterion of Schwarz with maximum of five.
** Indicates the significance level at 5%. *** Indicates the significance level at 1%.

We have also reported results pertaining to multicollinearity diagnostics of the variables used in this study as in Table 4. The choice of non-parity variables used in this study is thus restrictive to the results of the multicollinearity test.

Table 4: Multicollinearity (Variance Inflation Factor) Test Results

Variable	**VIF**	**1/VIF**
PPP	5.77	0.173255
IFE	1.54	0.648061
CAGDP	1.40	0.716580
TTRADE	6.98	0.143360
TRESM	1.70	0.588454
BOP	1.33	0.752885
NCA	2.74	0.365419
Mean VIF	**3.06**	

* VIF values of more than 10 shows significant multicollinearity.

No evidence of multicollinearity is found given the test statistics (VIF) are below 10. Hence, the way we have defined the variables, and transformed them, there is no multicollinearity-driven error in our parameter estimates.

Consistent with panel unit-root tests, the panel cointegration tests tend to reveal more powerful and reliable estimates on the two key variables, the prices (PPP) and interest rates (IFE). The test for the presence of cointegration between the panel-based variables is conducted after ensuring that the variables are integrated of order one, denoted as *I(1).* If the series are cointegrated, then the residuals would be integrated of no order, i.e. *I(0)*. Pedroni (1999, 2004) proposed several cointegration tests for panel data. A distinctive feature of this test is that it allows for considerable heterogeneity: see Table 5.

Furthermore, there is a possibility to include multiple regressors so that the conintegration vector varies across different sections of the panel, and also controls for heterogeneity in the residuals across cross-sectional units.

Table 5: Panel Cointegration Test of Two Tests, Parity vs. Parity and Non-Parity
Table below reports the statistics on Pedroni's test of cointegration. The test is conducted on two different models, one which include parity and non-parity factors and the other which only includes parity variables, as independent variables.

Variables N = 2 T = 120	$\mathbf{NER = f(Parity \,\&\, Non\text{-}parity)}$		$\mathbf{NER = f(Parity)}$	
	Model without Trend	**Model with Trend**	**Model without Trend**	**Model with Trend**
Pedroni Cointegration				
Panel v-stat	0.1548	-0.3822	2.8298***	1.3381
Panel rho-stat	-0.7447	-0.1841	-2.7065***	-1.7750**
Panel pp-stat	-1.8284**	-1.8080**	-3.3609***	-2.8315***
Panel adf-stat	-1.7581**	-1.7835**	-3.3203***	-2.7534***
Group rho-stat	-0.5962	0.0779	-2.2308**	-1.2282
Group pp-stat	-1.9986**	-2.0607**	-3.8451***	-2.8531***
Group adf-stat	-1.8832**	-2.0400**	-3.8031***	-2.7621***

** Indicates the significance level at 5%. *** Indicates the significance level at 1%.
The number of lags is determined by the criterion of Schwarz with maximum of fourteen.

The result of the Pedroni's cointegration test is reported in Table 4 as follows. Two different equations are taken into consideration: one which include parity and non-parity variables, and one that includes only parity variables (second half of the table). The cointegrating relationship between the parity variables holds, given that all seven test statistics are significant at 5 and 1 per cent significance levels.

5.3 Dynamic OLS Results

In this section, we present test results to show the robustness of the results discussed in the previous sections. These results are obtained for a two-country scenario, namely the US and the UK currencies. Tables 6(a) and 6(b) reports the results for the DOLS test. This test is developed by Kao *et al.* (2001) as an extension to the study of Stock *et al.* (1993).

Table 6(a): Results of Dynamic OLS Estimation: Data set over 1960-2014

Table below reports statistics on the Dynamic OLS test of cointegration as a robustness test to the Pedroni cointegration test. Four different specifications are taken into account to identify the best model that fits the requirement of long-run relationship between variables.

Variables N = 2 T = 220	$\mathbf{NER = f(Parity}$ & Non-$\mathbf{parity)}$		$\mathbf{NER = f(Parity\ )}$	
	DOLS (Lag = 2, Lead = 1)	**DOLS (Lag =1, Lead = 2)**	**DOLS (Lag = 2, Lead = 1)**	**DOLS (Lag = 1, Lead = 2)**
LCPI	0.064	0.095	0.134	0.185
	(0.69)	(1.03)	(1.38)	(1.91)*
RIFE	3.15	0.380	1.99	-4.05
	(10.78)***	(1.30)	(6.35)***	(-12.92)***
CAGDP	-0.541	-0.643	-	-
	(-1.96)**	(-2.33)**		
TTRADE	0.300	0.225	-	-
	(0.93)	(0.69)		
TRESM	0.040	0.038	-	-
	(8.50)***	(8.21)***		

* Indicates the significance level at 10%; ** Indicates the significance level at 5%; and *** Indicates the significance level at 1%.

One of the basic aims of this test is to correct for endogeneity bias and serial correlation, so as to bring about standard normal inferences of the estimators. The estimators of DOLS augment the static regression with certain lags, leads as well as contemporaneous values of the regressors in first differences. The outcome would be more precise estimation as well as more powerful tests compared to simple cointegration tests, given that the information about the cointegrating vectors is pooled. Furthermore, the estimator of the DOLS is straightforward for the sake of computation, and relevant test statistics have standard asymptotic distribution (Mark *et al.*, 2003). The two parity theorems of PPP and IFE are always considered as long-run equilibrium theories. Here we have, for the first time, both variables becoming strongly significant because these tests are the most refined tests to-date that yields reliable results. Hence, the significance of both prices and interest rate differences in the Table 5 finally shows that the parity theorems hold very well with strong correlations with the nominal exchange rate.

The test results for the period of free-floating era is shown in the next table (6(b)).

Table 6(b): Results of Dynamic OLS Estimation: Data set over 1984-2014

Variables N = 2 T = 120	NER = f(Parity & Non-parity)		NER = f(Parity)	
	DOLS (Lag = 2, Lead = 1)	**DOLS (Lag =1, Lead = 2)**	**DOLS (Lag = 2, Lead = 1)**	**DOLS (Lag = 1, Lead = 2)**
LCPI	0.212	0.315	0.117	0.156
	(0.72)	(1.07)	(0.39)	(0.52)
RIFE	-2.477	-8.609	-1.112	-4.530
	(-3.81)***	(-13.22)***	(-1.66)*	(-6.75)***
CAGDP	-0.391	0.082	-	-
	(-0.83)	(0.17)		
TTRADE	-0.822	-1.337	-	-
	(-2.00)**	(-3.25)***		
TRESM	-0.028	-0.061	-	-
	(-1.37)	(-2.91)***		
BOP	-0.061	0.0431	-	-
	(-2.02)**	(1.41)		
NCA	15.168	15.309	-	-
	(2.06)**	(2.08)**		

Comparing the two results for pre-to-post and the post-Bretton Woods periods indicates that the results are broadly similar (second half of the table is striking). In either case, the CPI is not always significant as a factor for the nominal exchange rate changes if the model uses more than parity factors. When appropriate lead and lag are specified, the results as in Table 6(a) shows that the longer period data reveal both price and interest rate are significant. When a shorter period is used (120 quarters) the price factor is not significant.[4] With a long period data set, and with applied DOLS, we show that the parity factors are significantly affecting the exchange rate.

The coefficient for the PPP factor is tested using a 2-lag and then refining it to a 1-lag specification. The tests show that the coefficient with one lag and 2 leads (0.185 with a t-value of 1.91) is statistically significant at 10 per cent level. Further, the coefficient on IFE is -4.05 with a t-value

[4] A very useful comment was made by an anonymous reviewer to include more variables than the ones we had included in the test model. The data series for the extra variables on the applied intervals of time do not go beyond 1985: so the second test with more factors only covers the post-Bretton-Woods period as shown in the Table 5(b).

of -12.92 is significant at 1 per cent level. The directions of the variables are consistent with the theorems (see Table 1). That is, changes in *prices and interest rate differences across the two developed trading nations do significantly determine the changes in the nominal exchange rate*. This finding is in support of the parity theorems as holding in the long run over fixed-and-free floating as well as during the free floating periods.

To augment this result, we used non-parity factors as control variables (see the statistics in the first half of the table). The results indicate that the inflation is not a significant variable with non-parity factors introduced in the model. However, the real interest rate is significant (3.15 with 10.78 t-value) is statistically significant at 1 per cent level. The results with non-parity variables did not reveal PPP to be a significant factor. Thus, testing the parity theorems alone (see second half of the table) with a dynamic model with lags and leads reveals support for the parity factors as significant for exchange rate determination. Two of the three non-parity factors are significantly correlated with nominal exchange rates of the US and the UK.

5. Conclusion

This paper is a renewed attempt using more appropriate econometric methodology to re-state the often-tested parity theorems from monetary economics point of view. The reason for revisiting this research are: there is only weak support to-date for these theorems, especially PPP, despite lots of studies; and the existing literature suggests that a more appropriate econometric approach is needed to reveal the underlying behaviour to solve this “puzzle”. We use a long length time series of 220 quarterly observations in one test and 120 quarters covering the free-floating recent period. Our maintained hypotheses are that the relative prices and relative interest rates across two trading nations are significant factors for exchange rate formation. The US and UK data were used since data are available for these economies readily for a long length of time. The methods used are panel cointegration and the robust DOLS.

The results revealed that both the PPP and IFE theorems are strongly supported, which is a new finding for the US-UK data set for 1960-2014 period and 1984-2014. If the correct lags and leads are specified, and if the interest rates are computed as real interest rates in a dynamic model, then we note that a simple test of just the parity factors provide support for the parity theorems. An extended data set using many more variables would also be relevant, but in our tests, not all non-parity factors turn out to be significant whereas a re-specification of parity factors alone showed a significant relationship with nominal exchange rate.

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Appendix:

Figure 1: International Reserve Trend over 1960-2014