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Testing empirically the Purchasing Power Parity Model: An examination of exchange rate determination between Indian Rupee and US Dollar

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Abstract
The adoption of the flexible exchange rate regime after the collapse of the Bretton Wood system of fixed exchange rate has put economies at huge risk. Adverse movements of exchange rate have implications at Macro level; at the firm level and at individual level such as for traders and other participants in forex market. Economists have been trying to predict exchange rate by developing many models so that a forecast can be made in order to deal with uncertain future. The Paper tests both the Absolute and Relative versions of PPP model and whether it holds true between India-USA or not. It is observed that all the variables trended at level. Next, checked for cointegration using the Engle-Granger two step method and found that a long run relationship exists between variables in each of the Absolute and Relative versions. Both Absolute and Relative versions fail to have a long run relationship However, relative PPP model performed better in estimating the exchange rate than the absolute version.

Keywords: Purchasing Power Parity, Exchange Rate, Time Series Analysis, Granger Causality Test, Cointegration.
JEL Classification: F4

Introduction

Today countries trade with each other on an unprecedented scale. The adoption of flexible exchange rate regime after the collapse of the Bretton Wood system of the fixed exchange rate has put economies at huge risk. Adverse exchange rate movements have implication at macro level such as Balance of Payment, Current account deficit and overall macroeconomic fundamentals; at the firm level- If domestic firms have foreign debt obligations and over the period the exchange rate rises (depreciates) then firms will have to pay more in terms of domestic currency. This reduces profits for the firm, which can used for future investment prospects. Exchange rate movements also impact individuals such as traders and other participants in the forex market. Lastly, the Monetary authority also intervenes in the forex market to curtail volatility in exchange rate movements. Whenever the exchange rate changes macroeconomic variables related to it need to adjust every time. All of these make the mechanism and dynamics of the exchange rate an interesting area for research.

Economists have been trying to model the exchange rate for more than two centuries. Many models have been devised to determine exchange rate movements and to some extent, reasonable forecasting of the exchange rate can be done so that adequate preparations could mitigate any unforeseen circumstances.

In this paper we look at the Purchasing power parity model (hereafter PPP)

The PPP Model.

PPP model is an exchange rate determination model. (Krugman, Obstfeld, & Melitz, 2012). It is also called as "inflation theory of exchange" by (Dornbusch, 1985). It enjoys the same status as the quantitative theory of money does in economic literature. It was first proposed by a British economist, David Ricardo, in the 19th Century. It was put in mainstream economics by a Swedish economist, Gaustav Cassel, in the 20th century. Since then, many studies have been undertaken to check whether the model holds or not.

Before discussing the PPP model, it is important to discuss "the law of one price". "The law of one price" states that if a market is competitive, free from transportation cost, and other barriers like tariffs, then similar goods should have the same prices across countries when all prices are expressed in terms of same currency (Krugman, Obstfeld, & Melitz, 2012). It is expressed as

$P_i = SxP_i^*$

where P_i is price of good 'i' in domestic market and P_i^* is price of good 'i' in foreign market.

For example, if the Rs-$ exchange rate is Rs40/$1 i.e. it takes 40 rupees to buy a dollar and if a cold drink bottle costs Rs. 80 in India then it should cost $2 in the US. If the exchange rate is not equal to Rs40/$1 then an arbitrage opportunity will emerge where an arbitrageur will trade between cheaper and expensive market and will make a risk-free profit, assuming that there are no transportation cost and other impediments to trade. For example, if the exchange rate would have been Rs30/$1 and the cold drink bottle still cost $2 in the USA (in terms of Rs it will cost Rs 60) the arbitrageur will buy from USA and sell it in India at Rs 80 and make a profit of Rs 20 per bottle assuming there is no transportation cost, etc. Note here that all prices/costs are expressed in Rs.

The PPP model has two versions- one is the . "It states that the exchange rate between countries must be such that it equals the ratio of price levels". In equation, it is expressed as

$E_t = P_{t\ IND}/P_t$

where P and P* are domestic and foreign price levels. For example, if a commodity basket costs Rs 400 in India and $10 in the USA then the exchange rate as predicted by PPP must be 40Rs/1$. If prices in the US rise to say $20 for the same basket, then the exchange rate must be decrease to 20Rs/1$ i.e. the currency appreciates. PPP theory, therefore, says that if the purchasing power of the home currency falls, which is reflected in rising prices, then the exchange rate must depreciate and if purchasing power rises then the exchange rate must appreciate.

It might look from equations of "the law of one price" and "Absolute PPP" that the two are same but it is not the case. 'The Law of one price' holds for one commodity but PPP holds for a commodity basket (entire economy). The price level in PPP is made up of prices of various commodities by making a commodity basket. (Dornbusch, 1985) discusses about the strong/ absolute version of PPP and postulates that it relies on the 'law of one price'. It consider taking a domestic price index of many goods and services $P = f(p_1, p_2, p_3, \ldots\ldots p_n)$ and a foreign price index $P^* = g(p_1^*, p_2^*, p_3^*, \ldots\ldots p_n^*)$. When prices are equalised and the same goods and services enter the commodity basket with the exact same weights in both the indexes only then will Absolute PPP holds. However, it must be noted that commodity baskets will be different for different countries (Krugman, Obstfeld, & Melitz, 2012).

The weak/ relative version of PPP states that the percentage change in the exchange rate equals the difference between the percentage change in price levels in each country" (Salvatore, 2013). For example, if prices rise by 5% in India and by 2% in the USA then relative PPP predicts a depreciation of the Indian currency by 3%. Pilbeam (1998) describes that the exchange rate will adjust by the amount of the inflation differential between two economies. Mathematically it is expressed as follows.

$$\left\{\frac{E_t-E_{t-1}}{E_{t-1}} * 100 = \left(\frac{P_t-P_{t-1}}{P_{t-1}}\right) * 100 - \left(\frac{P_t^*-P_{t-1}^*}{P_{t-1}^*}\right) * 100\right.$$

Literature Review

Zyoud (2015) and (Yong & Ling), both these papers test the empirical validity of Absolute as well as Relative PPP. While the former paper deals with exchange rate between US dollar and Canadian dollar, the later deals between US dollar and Singapore dollar. Zyoud argued that most of the traded goods are heterogeneous and that consumption basket differs across countries and hence expected that absolute PPP will not hold. Both conclude that Absolute PPP does not hold in the long run based on Engel Granger cointegration test as it failed to any long run relationship.

With respect to Relative PPP, Yong and Ling concludes that relative PPP does hold in the long-run using the cointegration test between the Singapore - US-dollar exchange rate. Further, to check for short run dynamics an error correction model was developed for relative PPP. It was found to explain short-run dynamics reasonably well. In Zyoud's paper, it was observed that inflation differential though important in explaining the exchange rate movements, it does not perfectly fits the relative PPP model as the values of the regression coefficient was not as expected. However, the study was restricted to a shorter time duration.

It can said that relative PPP performed better, though not perfectly, than absolute version in case of forex between American and Canadian dollar.

Islam (2013) investigates the existence of Absolute PPP. Islam looks in the bilateral trade between two neighbouring trading partners i.e. between India and Bangladesh. It was found that absolute PPP does not hold as there was no long run relationship between the variables i.e. the exchange rate and the GDP deflator (as proxy for price variables). It checked for long run relationship using the Johansen and Juselius test and found that the variables were not cointegrated and thus PPP does not exist. It further checks for causality using granger causality test and found no unidirectional causality. It attributes restrictive trade policies like high duties and tariff as a major reason.

Contradictory to the finding in the above three papers, Hsieh (2009) finds that Absolute PPP does hold true in case of exchange rate determination between Indonesian Rupiah and the US dollar. The paper checks the PPP model by taking two price indexes- one Consumer Price index (CPI) and the other producer price index (PPI). It was observed that using relative PPI as proxy for prices was better in explaining the exchange rate dynamics and predicting exchange rate than the relative CPI.

Hauner, Lee, & Takizawa (2011) looks at question whether relative PPP can be used to form expectations about future exchange rates. For this, they regressed the expected appreciation of the currency on the expected inflation differential. Defined regression equation as NER=C_0 + C_1(INF H_e – INF F_e). If relative PPP has to hold the intercept term must be 0 and slope must be 1 with a negative sign. If the consumption basket is made up of only tradable goods, then C_1=1 and C_0= 0, otherwise not.

Using data for 55 developed and developing country it was found that the slope coefficient was estimated to be between -0.5 to -0.6 (less than 1 but the sign is as expected) and significant. Thus, indicating that relative PPP can be used for forming exchange rate expectations. The paper also highlights that relative PPP effects strengthen when the exchange rate regime is flexible compared with a fixed exchange rate regime or a regime with tight controls.

Data and Methodology

In this Paper Monthly data on nominal exchange rate and consumer price index of India & USA have been taken from the OECD Stat website. CPI base year is 2015. Data starts from 1991 M1 and ends at 2020 M1. In total 349 data points which is quite large and can capture long term relationships, if any. All data are seasonally adjusted.

Here we test the validity of both Absolute and Relative PPP.

The absolute PPP regression equation will be $E_t = \frac{P_t}{p_{t^*}}$.

Converting it into log form and inserting an intercept we get

$\log E_t = \alpha + \log P_t - \log P_t^*$

which is also written as $s_t = \alpha + \beta_1 p_t - \beta_2 p_t^*$.

The regression equation for relative PPP in log form is-

$\Delta S_t = \alpha + \beta_1(\Delta p_t - \Delta p_t^*)$.

Absolute and Relative PPP theory is a long run theory, thus cointegration is expected to exist between the variables.

Empirical Strategy:

We first check for Integration level I(.) of the series that is at what level the series becomes stationary. If we don't check for stationarity and simply estimate a model then there are high chances that regression results will be spurious and hence not reliable. We will use the 'Augmented Dickey-Fuller' (hereafter ADF) test to examine whether the series is stationary or not. The common method is to test for unit root. The null hypothesis is – presence of unit root, indicating that the series is not stationary. The alternative hypothesis- no presence of unit root, meaning the series is stationary. If the series is stationary at its level, it is written as I(0). If the series becomes stationary after taking the first difference, then it is written as I(1).

If we find that series are I(0) we simply estimate the model using the least square method. If all the series are I(1) we will look at the variables and try establish long run relationship between them. This is done through cointegration test. Since the model at hand is a single equation model, we use 2 step Engle granger method to check for cointegration. This is done by running least square regression on I(1) series, then generate residual series and test for stationarity of the residual series. If residual series is I(0) then we conclude that variables does have a long run relationship. The cointegration is present simply means that a linear combination of variables in a model is stationary. We express that linear combination in terms of the residual. Thus, if the residual series is stationary then the linear combination is also stationary. If cointegration exist then there must an error correction mechanism that will take into consideration short run shocks. If the integration level of the series are different, some are I(0) and others are I(1) then we use Auto regressive distributive Lag model (ARDL). However, use of ARDL was not required.

It is rarely found that any economic variable is stationary at its level and therefore we expect that exchange rate, domestic and foreign prices will all be I(1). For absolute PPP to hold the cointegrated vector must be (1,0,1, -1). The elements of the cointegrated vector is nothing but the coefficient of the least square estimates. The expected sign of these estimates is reflected in the cointegrating vector.

When we check for relative PPP all the variables was in first difference form. Thus the variables must be I(0). If this was so we simply estimate using least square method. When all the variables are I(0) they will be cointegrated as well. Thus, the expected sign for coefficient must be positive for Δp_t term and negative sign for Δp_t^* and for relative PPP to hold coefficient values must be (0 for intercept and 1 for slope coefficients) in the estimated regression equation.

Results

The best way to analyse PPP models is to start by plotting a graph of actual and PPP predicted exchange rate. In graph 1 presented below we have plotted (absolute PPP) actual exchange rate in blue and the PPP predicted exchange rate in orange. It might look like the PPP predicted exchange rate is a straight line, but it is not. Its value lies between 0 & 2. Since the data is large, we cannot possibly plot each month’s because of lack of space.

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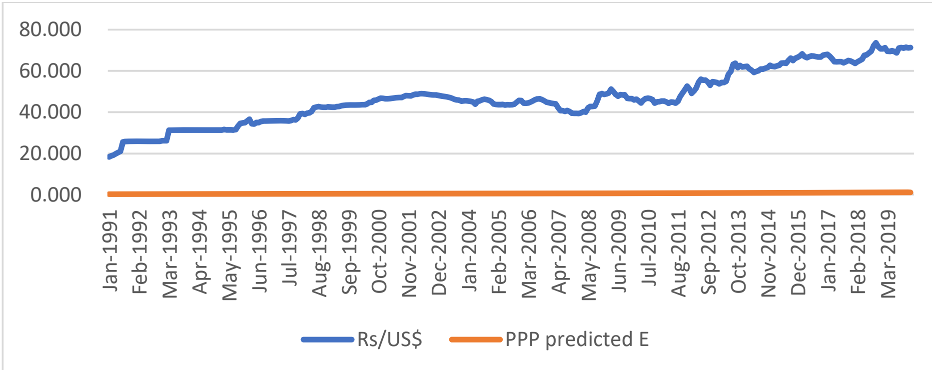
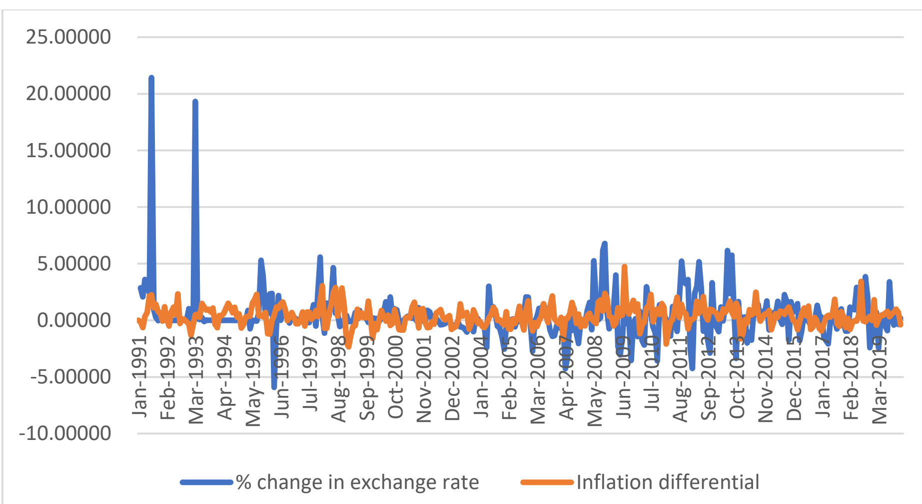
Graph 1: Trend of actual and Absolute PPP predicted exchange rate from Jan-1991 to Jan-2020



Source: 'Data on Actual exchange rate and CPI of India & USA collected from OECD Statistics'.

Looking at the graph 1 it is clear that there is huge discrepancy between actual and PPP predicted exchange rate and that one can conclude that Absolute PPP does not hold for India with USA. We now estimate the model to see if this is actually true.

Graph 2: Trend of change in Actual exchange rate and Inflation differential from Jan-1991 to Jan-2020



Source: Using actual data on exchange rate and CPI of India & USA collected from OECD Statistics, change in actual exchange rate and inflation differential is calculated using equation-1 from the introduction section.

Graph 2 plots percentage change in exchange rate (in blue) and inflation differential (in orange). Inflation differential is calculated using the formula defined earlier in the introduction section. Seeing the graph, one is tempted to say that Relative PPP will not hold. Had the graphs been completely overlapping then one could have concluded that relative PPP holds for India. We start by checking trend. That is, we check for stationarity or integration level of each series. We have used the ADF test whose results are summarised in the table below - Table 1, in appendix, shows result of each series at its level. Table 2, in appendix, shows result at First Difference. Level of significance chosen is 1%.

We thus conclude from ADF test that all the variables in consideration are stationary at First difference.

Empirical Test for Strong/ Absolute PPP

We now use the 'Engle Granger two step' to check the validity of Absolute PPP. Results are shown below in the table. We find that the error term series is cointegrated (Table 4). Hence, we can conclude that there exists a long run relationship between exchange rate and prices. However, the cointegrated vector that is estimated is (1,2.09,0.77, -0.91) shown in table 3 in the appendix is different from our expected cointegrated vector (1,0,1, -1). Sign of all the coefficient is as expected and the coefficients are also statistically significant. We also performed Granger Causality to check which way the causality is moving i.e. from price levels to exchange rate or vice-versa. We found that none of the variable granger causes the other variable. We thus conclude that the PPP's absolute version does not hold in the long run but price levels of India and USA are important since there exists a long run relationship. However unidirectional causality is not present. Hence, we don't check for short run shocks.

Empirical Test for Weak/ Relative PPP

We now check for relative PPP. Equation that we estimate is $\Delta s_t = \alpha + \beta_1 (\Delta p_t - \Delta p_t^*) + \varepsilon_t$. . Note here that all the variables are at 'first difference'. Hence, they are stationary at level i.e. they are I(0). Variables will automatically be cointegrated. We now estimate the above equation using least square method. Results are shown in table 5 in appendix. The coefficient values are (0.00, 0.35) which is different from (0,1) for relative PPP to hold. Signs are as expected and coefficient are statistically significant. Here again we checked for granger causality which tells us that none the variables in the model Granger causes the any other variable. We thus conclude that relative PPP do not hold in the long run but inflation differential is an important variable that affects exchange rate as there exists a long run relationship but no unidirectional causation is inferred. Thus, relative PPP does not hold as a long run relationship. Hence, we don't check for short run shocks.

Possible Reasons for Failure of PPP

The theory based on the "law of one price". In reality it is difficult to validate this law. (Dornbusch, 1985) had already given us a hint of why the theory will not hold perfectly. However, if we assume that law of one price holds even then PPP might not hold. This is because PPP uses price indices to calculate exchange rate. These price indices are constructed using a basket of goods and services. All goods and services do not get equal weightage in the basket. The basket of goods used to construct CPI for USA and for India are very different. Even if we assume (for theoretical purpose) that basket has same goods it is not possible to have same weights for each good in both the commodity basket to make them exactly same. The good's basket will be different for India and USA because demand and consumption pattern are different in these countries.

It has been seen that monetary authority in developing countries intervene a lot more than developed countries in the forex market, thus cause the rate to stay well above or below the PPP predicted rate. Speculators in the forex market also play a vital role in exchange rate movement. High speculation will lead to exchange rate movement that is not guided by PPP (Islam, 2013).

It is assumed in the PPP theory that there is no transportation cost, no barriers to trade, perfect competitive market structure. All these assumptions are hard to meet in reality. There are no reason(s) to believe that there will be no transportation cost between India and US since the distance between the countries is large. Transportation either through sea or via air are the only two way to transport goods and both are costly. Adding transportation cost will disturb the law of one price when exchange rate is not adjusting. Making thing more complex there are barriers to trade such as Tariffs. Tariffs are usually imposed to protect domestic producer from foreign competition. Note here that in developing country like India non-tradable segment is higher than in USA. This will have impact on exchange rate movements and leads to deviations from PPP predicted exchange rate (Krugman, Obstfeld, & Melitz, 2012).

Conclusion

The analysis of Purchasing Power Parity (PPP) in the context of exchange rate determination between India and the USA provides mixed evidence regarding the applicability of PPP theories. The empirical results suggest that absolute PPP does not hold in this bilateral trade scenario. The substantial discrepancies between the actual exchange rate and the PPP-predicted exchange rate, as depicted in the graphical analysis, support this conclusion. The relative PPP holds more validity though not a perfect one. These findings are in line with the broader economic literature that posits relative PPP as a more realistic model due to the presence of market imperfections such as transportation costs, tariffs, and non-traded goods. Future research could benefit from incorporating more rigorous econometric techniques to further elucidate the dynamics of PPP in different economic contexts.

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Appendix

(Table 1)

Result of Unit Root test for Stationarity of each Time series variable at Level using Augmented Dicky Fuller method.

Variable	Test Type	Model Type	P value	Interpretation
Log E	ADF	Trend & Intercept	0.012	Unit root present
		Intercept	0.04	Unit root present
		Without trend and without intercept	0.99	Unit root present
Log P	ADF	Trend & Intercept	0.70	Unit root present
		Intercept	0.66	Unit root present
		Without trend and without intercept	1.00	Unit root present
Log P*	ADF	Trend & Intercept	0.78	Unit root present
		Intercept	0.34	Unit root present
		Without trend and without intercept	1.00	Unit root present

Source: Author’s calculation using the Eviews’s student version

(Table 2)

Result of Unit Root test for Stationarity of each Time Series variable at First difference using Augmented Dicky Fuller method.

Variable	Test Type	Model Type	P value	Interpretation
Log E	ADF	Trend & Intercept	0.0000	No unit root
		Intercept	0.0000	No unit root
		Without trend and without intercept	0.0000	No unit root
Log P	ADF	Trend & Intercept	0.0000	No unit root
		Intercept	0.0000	No unit root
		Without trend and without intercept	0.0067	No unit root
Log P*	ADF	Trend & Intercept	0.0000	No unit root
		Intercept	0.0000	No unit root
		Without trend and without intercept	0.0000	No unit root

Source: Author's calculation using Eviews's student version

(TABLE 3)

LEAST SQUARE ESTIMATE FOR ABSOLUTE PPP

LOG E = C(1) + C(2)*LOG P - C(3)*LOG P(FOREIGN)

		Standard Error	t-stat	Probability
COEFFICIENT_1	2.093227	0.222226	9.419365	0.0000
COEFFICIENT_2	0.777418	0.55587	13.9856	0.0000
COEFFICIENT_3	-0.916453	0.164505	-5.57097	0.0000
R^2	0.88869			
Adj R^2	0.888045			
Regression's S.E	0.041456			

Source: Author's Regression calculation using Eviews's student version

Table 4

Result of Residual Series 'Unit Root Test'

Null Hypothesis: RESID01 has a unit root			
Lag Length: 1			
		t-stat	probability
ADF test statistic		- 4.13102	0.0000
Critical values	1%	- 2.57164	
	5%	- 1.94174	
	10%	- 1.61609	

Source: Author's calculation using Eview's student version.

TABLE 5

LEAST SQUARE ESTIMATES OF RELATIVE PPP

LOG ESA = C(1) +C(2)*(LOGPSA-LOGPFSA)

		Standard Error	t-stat	Probability
COEFFICIENT_1	0.001083	0.000544	1.991548	0.0472
COEFFICIENT_2	0.358349	0.152567	2.348792	0.0194
R^2	0.715694			
Adj R^2	0.71285			
Regression's S.E	0.008907			

Source: Author's calculation of Regression using Eview's student version