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Purchasing Power Parity and Exchange Rate Management Under Managed Float: Case for INR/USD

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Abstract

Purchasing Power Parity (PPP) doctrine has been a significant topic in the domain of international finance and economics. Several studies have been conducted on the issue of testing the soundness of the PPP hypothesis but a very few studies have been done for developing nations, particularly for India. This study tried to empirically test the PPP hypothesis for Indian rupee/US dollar (INR/USD) rate using quarterly data for the period 2001:1 – 2024:2. The stationarity of the relevant variables is examined by using the econometric tool of Augmented Dickey Fuller (ADF) and Phillip - Perron (PP) tests. To confirm empirical validity of PPP hypothesis, OLS regression technique is used. Autocorrelation problem is removed with the help of AR1 (Cochrane-Orcutt) and maximum likelihood procedures. The PPP model is estimated in naïve static form as well as the partial adjustment framework. The partial adjustment framework helps to find out the speed with which the actual exchange rate moves towards and reaches its equilibrium level. The empirical findings show that absolute PPP does not work well in its naïve static form, but it works well in partial adjustment framework with 2.5 quarters being speed of adjustment. The relative PPP is found to work well in both frameworks with 1.5 quarters as speed of adjustment. Thus, the policymakers may use the PPP hypothesis for exchange rate forecasting. Also, it is suggested that the policymakers should carefully consider the effect of internal or external shocks on PPP and tailor their monetary policy measures accordingly.

Keywords: Purchasing Power Parity, Exchange Rate, Relative Prices, Regression, ADF Test, Unit Root, Stationarity

JEL Classification: E31, F31, C15, C32

Introduction

The building block of exchange rate modelling is the principle of Purchasing Power Parity (PPP), although its continuous validity in the real world is questioned by most contemporary economists. Nonetheless, many economists view some variations of PPP as a reference point for long-term real exchange rates (Rogoff, 1996). This belief underlies much of the literature existing in international macroeconomics, which assumes that certain forms of PPP hold, at least as long-term relationships. Estimations of PPP exchange rates serve practical purposes, including assessing the extent of exchange rate misalignment and determining suitable policy measures, establishing parities between exchange rates, and facilitating assessment of GDP (gross domestic product) levels across the world. Existing literature on exchange rate mechanism is dominated with the PPP doctrine and therefore it is also viewed as a model of exchange rate determination and forecasting. In general terms, the PPP theory says that one should be able to buy exactly the same quantity of goods in any country for exactly the same amount of money (in value), i.e., the same commodity costs the same across the different economies when it is measured in terms of a common currency. If this condition does not hold, it would be profitable for the arbitragers to trade. This process of arbitrage will continue until there is no profit in doing so, i.e., until the above condition is again restored. The PPP doctrine can be viewed from two different versions. The first version of PPP strictly follows the law of one price, and it is called absolute PPP. The other version of PPP is known as relative PPP.

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Absolute PPP

In absolute terms, the PPP theory says that the price of a packet of goods in one economy must be same as that of the price of identical packet of goods sold in the other economy when converted into a common currency by using exchange rate, implying that the two prices would be same i.e.

$$P_T = SP_T^* \text{ or}$$

$$S = \frac{P_T}{P_T^*},$$

wherein, S denotes exchange rate which is the ratio of prices of tradables in the two economies.

If the price level in a country is the weighted sum of price levels of tradables and the non-tradables with their corresponding shares in the total output as weights, we have.

$$S = K\frac{P}{P^*}$$

wherein, k represents sectoral shares and relative sectoral price levels, P* and P, are general price levels of the foreign and domestic economy.

As per the above equation, exchange rate equals the relative price levels of the two economies. This theory is referred to as absolute PPP.

Taking log on both sides, we have:

$$\log S = \log k + \log P - \log P^* \text{ or}$$

$$s = k + (p - p^*)$$

Relative PPP

In case of relative version of PPP, we consider the exchange rate at two different points of time. Suppose that at '0' point of time the spot rate is given by:

$$S_0 = K.\ (P^{Rs.}{}_0/P^{\$}{}_0)$$

And at time '1' it is given by:

$$S_1 = k(P^{Rs.}{}_1/P^{\$}{}_1)$$

It is assumed that the exchange rate changes at $\dot{s}$ rate per unit time, the domestic price level changes at $\dot{p}^{Rs.}$ rate per unit time and the foreign price level changes at $\dot{p}^{\$}$ rate per unit time. Since the rate of change is known, therefore,

$$S_1 = S_0(1+\dot{s});\quad P_1^{Rs.} = P_0^{Rs.}(1+\dot{p}^{Rs.}) \text{ and } P^{\$}{}_1 = P^{\$}{}_0(1+\dot{p}^{\$})$$

Putting these values in above equation, we get:

$$S_0(1+\dot{s}) = k\,[\dot{P}_0^{Rs.}(1+\dot{p}^{Rs.})/\ \dot{P}^{\$}_0(1+\dot{p}^{\$})] \quad \text{or}$$

$$(1+\dot{s}) - 1 = [(1+\dot{p}^{Rs.})/\ (1+\dot{p}^{\$})] - 1$$

$$\dot{s} = (\dot{p}^{\$} + \dot{p}^{Rs.})/(1+\dot{p}^{\$})$$

If $\dot{p}^{\$}$ is very small, $(1+\dot{p}^{\$}) \to 1$ and therefore,

$$\dot{s} = \dot{p}^{Rs.} - \dot{p}^{\$}$$

The above equation is known as the relative PPP. The relative PPP says that the expected rate of change in the exchange rate between two economies equals the expected inflation rate differential.

Objectives of the Study

The volatility of exchange rates remains a complex issue that requires further investigation. Given the substantial variations observed in exchange rates across different economies, it is undeniable that comprehending foreign exchange markets holds great significance. As very few studies have been taken up for testing the empirical validity of PPP for developing nations particularly for India and the USA, the present study tests the PPP between the two economies particularly during the managed float period. The results could be helpful or used as a tool for the policy maker for monitoring and designing foreign policy. Also, the study would add to the literature on PPP for developing nations with fresh evidence.

Review of Literature

The validity of PPP theory has always been a subject of intense debate in international finance and economics. Several research studies have explored about the validity of PPP across different countries and different time periods. Johnson (1990) examined the PPP between the US and Canada using annual and quarterly time series data for the period 1870–1986 using the Johansen

cointegration procedure and found evidence supporting the PPP for every time horizon analysed. Kugler and Lenz (1993) investigated the PPP between the German Mark (DM) and 15 other currencies, for the period from January 1973 to November 1990 using Johansen-Juselius cointegration revealing that the PPP held for six European currencies but was rejected for four others, with mixed results for the remaining five. Michael, Nobay, and Peel (1997) reexamined PPP for five developed countries, utilising monthly and annual data from 1921 to 1992. They estimated ESTAR models, suggesting that the process followed an exponential autoregressive (EAR) process instead of a linear one. Papell (1997) tested PPP for 20 developed countries, using monthly and quarterly data from 1973 to 1994. The study found that PPP was held when using monthly rather than quarterly data. Hegwood and Papell (1998) reexamined PPP for five developed countries using annual data from 1900 to 1972. Their findings suggested that the PPP theory holds true, with exchange rate reverting to an occasionally changing mean. Culver and Papell (1999) investigated PPP for 21 developed countries on quarterly data for the period 1973 – 1996. Their findings supported the empirical validity of PPP in the long run. Various other studies, such as Serletis and Gogas (2000) and Xu (2003), explored different aspects of PPP, including its behaviour in chaotic dynamics, mean reversion in the movements of exchange rate, and its application in context of exchange rate forecasting. These studies contribute to our understanding of PPP in different regions and provide insights into the factors influencing its validity. Kakkar (2001) examined the trends of the Mexican-US dollar rate, on annual time series data covering the period 1955–1996. He used ADF and PP stationarity tests for checking the status of stationarity and employed canonical cointegrating regressions (CCR). Their findings suggested cointegration between the real exchange rate (RER) and the Mexican - U.S. relative price of non-tradables. Xu (2003) tested PPP and used it as exchange rate forecasting model for eight countries, taking the U.S. as the base country. The study utilised quarterly data from 1974:1 to 1997:4 and used Engle-Granger cointegration procedure. The findings indicated that long-run PPP for the US and the eight trading partners considered in the research, was strongly rejected when coefficient restrictions were imposed. Nusair (2004) empirically tested PPP for a group of six Asian economies, including Malaysia, Philippines, Korea, Indonesia, Thailand, and Singapore, using different base countries. The study employed quarterly data from 1973:2 to 2000:1. The findings indicated mixed evidence for PPP across the countries and base countries.

Alba (2005) conducted an analysis of PPP for long-run using panel unit root test on the US dollar exchange rate of eighty-four developing and developed economies from 1976–2002. The findings indicated that PPP holds true in Latin America and Europe but not for Asia and Africa. Basher (2007) investigated the stability of the real exchange rate for 17 OECD (Organisation for Economic Co-operation and Development) nations using unit root test from 1973: Q1 - 1998: Q4, and they concluded that the PPP hypothesis stands valid. P. K. Narayan et al. (2009) examined PPP for the duration 1973–2002 and found that the PPP theory holds for 14 countries. Hüseyin Kalyoncu et al. (2010) examined black-market rate and official real exchange rate data for 13 countries during the time span 1970–1998 to collect evidence for soundness of PPP and found that the PPP held true for 10 countries.

While there are researchers who argue against the validity of PPP, Chang, Su, and Lee (2012) indicated that the PPP hypothesis stands valid in case of majority of East Asian economies, covering South Korea and Japan. Lee and Chou (2013) found that PPP was not found valid for G20 economies during the period 1994–2010. Their study suggested that PPP did not work for the countries included in their analysis. Gasaymeh and Kasem (2015) conducted an examination on Jordan and its trading partners including Turkey, the United States, Japan, and the United Kingdom, to evaluate both weak and strong forms of the PPP concept. Their cointegration test indicated a long-term association between exchange rate and domestic and foreign price levels, for all the nations. Khan and Ahmad (2015) investigated PPP as a condition for achieving equilibrium in the long run, for four Asian economies over a 25-year period from 1976 to 2001. Using a cointegration approach, they found no evidence of a cointegrating relationship in the sampled data, suggesting limited support for the PPP proposition in most cases. Srivastava (2015) tried to assess the utilisation of currency derivatives taking into consideration eighty-three non-banking companies of Indian origin that favour employing currency derivatives. He observed that these companies use currency derivatives to control cash flows

heling them to invest in more attractive opportunities from a growth point of view. He also found that variables namely debt ratio and income ratios play an important role in use of currency derivatives. Ümit (2016) examined the soundness of PPP during the time span ranging 2003:01 to 2015:10 and found that the PPP theory does not hold valid in South Africa or India. Ma, Li and Park (2017) challenged the PPP doctrine for Korea, China, and Japan using standard unit root tests. Their findings did not strongly support PPP for these countries. Bristy (2017) attempted to identify the variables that affect the exchange rate for the Bangladeshi economy for the time span 1999-2013. He used OLS regression and correlation methods and observed government expenditure as the most important factor influencing the exchange rate. The other identified factors were GDP, money supply, gross capital formation, gross national income, and primary income payments. Pilbeam and Litsios (2018) explored the PPP theory for Japanese Yen and the US Dollar to discover whether PPP principle explains exchange rates changes in long run. According to researchers, the continuous validity of PPP indicates that nominal exchange rates would not impact trade flows. However, if PPP holds true in long run, monetary fluctuations may influence real exchange rates (Chinn, 2019). Basanna and Vittala (2019) examined various strategies of foreign exchange risk management that are employed in the FMCG sector in India for the period 2010 to 2017. He found that EUR and US dollar dominated the forex market. The forward contract was found to be an effective hedging tool. Zayed et al. (2020) tested PPP for Turkey using Vector Error Correction Model, for the period 1958–2018. They used Johansen cointegration methodology Their empirical findings showed that PPP hypothesis is valid both in short run and long run for Turkey. Almutairi and Almutairi (2021) empirically tested the existence of PPP for France and U.S.A. in short run and long run, using monthly statistics. They applied Engle Granger cointegration test and VECM. Their results asserted that PPP theory holds for France and the US for the short-term period only. Du and Tho (2022) tested PPP between Vietnam and the United States for the period 1986–2014, with the help of Engle-Granger methodology, using annual data. They found the residuals obtained from the estimation to be stationary, showing a long-term association among real and nominal exchange rates. Thus, they concluded that PPP works between Vietnam and United States. Vo and Vo (2023) conducted an examination of purchasing power parity (PPP) by analysing cross-country panel data spanning 50 years after the Bretton Woods system collapsed. Their findings indicated that despite of the fluctuations in the value of currency and the presence of trade restrictions, the mechanisms of arbitrage process and resource reallocation were effective in mitigating many of these distortions over a longer timeframe. Additionally, they emphasised the relevance of the relationship between the exchange rate and price levels.

PPP has mostly been tested on major developed countries because these economies had market determined pricing systems. However, markets have been playing a major role in developing countries, but there have always been regulatory mechanisms to regulate markets, both real and financial. Overall, the literature presents a mix of evidence on the validity of PPP, with some studies supporting it and others challenging its applicability in certain contexts.

Research Methodology

This study tests the empirical soundness of PPP theory between India and the US. The study is conducted on quarterly data covering the period 2001:1–2024:2. The required data is secondary data, and it is collected from International Financial Statistics, a publication of the IMF. The consumer price index (CPI) (with base year = 2006) is taken as price level and the exchange rate is the INR/US dollar rate. Dummy variables are used to take care of any seasonal variations in the data. The variables used are first examined for stationarity with the help of ADF (1979) and PP (1988) tests. The ADF test of stationarity depends on the following regression:

$$\Delta Y_t = \beta_1 + \beta_2 T + \delta Y_{t-1} + \sum_{i=1}^{n} \alpha_i \Delta Y_{t-1} + \varepsilon_t$$

where Y_t represents the exchange rate, T represents the time trend, ε is the error term, and n denotes the optimal lag length which is required to take care of the autocorrelation in the estimated regressions. The Akaike Information Criteria (AIC) is applied to fix the optimal lag length. If the computed value is more than critical value given in the Mackinnon table, it will result in rejection of the null hypothesis (H0: d = 0) of the non-stationary of variable, and acceptance of the alternative hypothesis, implying stationarity of the variable at level and that variable is integrated of order zero (Gujarati &

Porter, 2009). The PPP hypothesis is tested following two different types of models: the naïve static form and the dynamic form. The dynamic form has been achieved either by adding the time series component (Somnath,1986) into the model or by deriving the equation from the partial adjustment framework. In the short run, multiple regression technique is used, and the models are estimated through OLS technique. If the regression suffers from an autocorrelation problem, AR1 (Cochrane-Orcutt method) process is used in the case of naïve static models and if the equation contains lagged dependent variable, the model must be estimated using the Maximum Likelihood method. The basic equation used is:

$$Y_t = \alpha + \sum_{i=1}^{n} \beta_i X_i + \varepsilon_t$$

wherein Y_t is the dependent variable and $\sum X_i$ is the set of independent variables.

If it is assumed that the above equation is a long run equilibrium model and that the actual level of the variable moves partially towards equilibrium level in a unit period, then, the speed with which it moves towards equilibrium can be ascertained. It will help to understand the short- and long-term behaviour of the variable taken into consideration, in response to movement in independent variables.

Models to be Estimated

Naïve static form of absolute PPP

$$s_t = \alpha + \beta\,(p - p^*) + \varepsilon_t$$

with the restriction on coefficient as, $\beta = 1$

Partial adjustment framework of absolute PPP

$$s_t = \alpha + \beta\,(p - p^*) + \varphi s_{t-1} + \varepsilon_t$$

with the restriction on coefficient as, $\beta = 1$, and $0 < \varphi < 1$.

Naïve static form of relative PPP

$$\dot{s}_t = \alpha + \beta\,(\dot{p} - \dot{p}^*) + \varepsilon_t$$

(where $\dot{p} = \dot{p}^{Rs.}$ and $\dot{p}^* = \dot{p}^{\$}$)

with the restriction on coefficients as $\alpha=0$ and $\beta=1$

Partial adjustment framework of relative PPP

$$\dot{s}_t = \alpha + \beta\,(\dot{p} - \dot{p}^*) + \varphi\,\dot{s}_{t-1} + \varepsilon_t$$

with the restriction on coefficient as $\alpha = 0$, $\beta = 1$, and $0 < \varphi < 1$.

Empirical Estimation of PPP

Testing Stationarity of the Variables

Before starting with the estimation of the models, the variables were tested for existence of unit root (stationarity) by applying ADF and PP tests. The obtained values of ADF and PP stationarity tests are summarised below:

Table 1: Unit Root Test of the Variables Used in Estimation

Variables	*ADF Values*	*PP Values*
Δs_t	-8.5293 I(1)	-5.1790 I(1)
$\Delta(p - p^*)$	-4.9105 I(1)	-4.3582 I(1)
$\Delta(r - r^*)$	-4.1030 I(1)	-6.5739 I(1)
$\dot{s}$	-8.6085 I(0)	-5.2027I(0)
$(\dot{p} - \dot{p}^*)$	-4.9179 I(0)	-5.6121 I(0)

Source: Author's Computation with the help of E-Views software.

Table 1, the relative price, exchange rate, and interest rate differential are I(1) at level whereas the rate of change in exchange rate and inflation rate differential are I(0) indicating that the linear regression will be testable and would provide meaningful results. MacKinnon critical values are used for taking decision on rejection of the null hypothesis, assuming the presence of a unit root in the variable.

Estimation of PPP

Absolute PPP (Naïve Static Form)

When the model was estimated, except for seasonal dummies, all other explanatory variables were significant at the 1% level of significance. However, the equation suffered with autocorrelation problem. Therefore, it was estimated by using AR1 process (Cochrane-Orcutt method). In the revised estimate, the variables were

significant at the 1% level, but the equation again suffered with autocorrelation problem. Therefore, the equation was again re-estimated with the help of the Cochrane-Orcutt method, and the following regression was obtained:

$$\mathbf{s_t} = \underset{(210.9035)^{*}}{3.5492} + \underset{(12.4527)}{1.1176\,(p - p^*)}$$

$R^2 = 0.9796$ $\bar{R}^2 = 0.9789$ DW- statistic = 1.4878
Rho (r) = 0.6955(7.4609)

Hypothesis Testing: $H_0: \beta = 1$, $H_1: \beta \neq 1$

In the above estimate, the relative price variable is significant at the 1% level, having a proper sign. The equation explains around 98% variations in the dependent variable. The short run elasticity of exchange rate with respect to relative price level variable is 1.1176, implying that the exchange rate is elastic (>1) with respect to price differential of the two economies. The hypothesis of unit elasticity of exchange rate is accepted at the 5% level. Thus, the PPP holds.

Partial Adjustment Framework of Absolute PPP

When the model was estimated in its partial adjustment framework, in the obtained equation, the variables were significant at the 1% level of significance except the seasonal dummies. DW-statistic was in the inconclusive range. Therefore, the equation was again estimated using the maximum-likelihood method, and the following regression was obtained:

$$\mathbf{s_t} = \underset{(3.6506)^{*}}{1.1874} + \underset{(2.7459)}{0.3505\,(p - p^*)} + \underset{(7.2111)}{0.6682\,s_{t-1}}$$

$R^2 = 0.9791$ $\bar{R}^2 = 0.9783$ DW– h = 1.4242

such that $0 < \varphi < 1$ where j is the coefficient of lagged dependent variable i.e. s_{t-1}

Hypothesis Testing: $H_0: \beta = 1$, $H_1: \beta \neq 1$

In the above regression, all coefficients are found to be significant at 5% level and the equation explains more than 97.5% variations in the dependent variable. The speed of adjustment towards the desired level is 0.3318 i.e. the actual level reaches the desired level in approximately three quarters. The elasticity of exchange rate with respect to relative price variable is 0.3505 in the short run, and in the long run, the elasticity is 1.0564. The hypothesis of unit elasticity of exchange rate is rejected at the 5% level.

Relative PPP (Naïve Static Form)

When the model was initially estimated, the inflation rate differential was significant at the 1% level with proper sign. However, the seasonal dummies were insignificant. The DW-statistic was in the inconclusive range. Therefore, the equation was again estimated using maximum-likelihood method and the following regression was obtained:

$$\dot{s}_t = \underset{(0.7037)}{0.0051} + \underset{(2.5465)}{0.8051\,(\dot{p} - \dot{p}^*)}$$

$R^2 = 0.1985$ $\bar{R}^2 = 0.1671$ DW- statistic = 1.7382
Rho (r) = 0.2514(1.8577)

Hypothesis Testing:

$H_0: \alpha = 0$, $H_1: \alpha \neq 0$
$H_0: \beta = 1$, $H_1: \beta \neq 1$

In the above equation, the inflation rate differential variable is significant at the 5% level with a proper sign. The equation explains 16.7% variations in the dependent variable. The short run elasticity with respect to inflation rate differential is 0.8051.

Partial Adjustment Framework of Relative PPP

After estimating the relative purchasing power parity in naïve form, when we moved to its partial adjustment framework, the variables were significant at 5% level of significance with expected signs. However, the seasonal dummies were insignificant and therefore dropped. The following equation was obtained as the final equation:

$$\dot{s}_t = \underset{(0.3328)}{0.0020} + \underset{(2.4636)}{0.7867\,(\dot{p} - \dot{p}^*)} + \underset{(1.7947)}{0.2285\,\dot{s}_{t-1}}$$

$R^2 = 0.1959$ $\bar{R}^2 = 0.1644$ DW– h = 1.7201

such that $0 < \varphi < 1$ where j is the coefficient of lagged dependent variable i.e. $\dot{s}_{t-1}$

Hypothesis Testing:

$H_0: \alpha = 0$, $H_1: \alpha \neq 0$
$H_0: \beta = 1$, $H_1: \beta \neq 1$

* values in the parentheses represent t-values.

In the above regression, inflation rate differential is significant at the 5% level with proper sign. The equation explains 16.4% variations in the dependent variable. Speed of adjustment is 0.7715, i.e., the actual level adjusts to the desired level in one and a half quarters. Short run and long run elasticities are 0.7867 and 1.0197 respectively. The hypothesis of intercept equal to zero and unit elasticity with respect to the inflation rate differential is accepted at the 5% level of significance.

Conclusion and Policy Implications

The empirical estimation results show that in the naïve form, PPP does not work. However, when the model is estimated in a partial adjustment framework, it works well. The variation explained by the two regressions is the same, but the degree of freedom of the first equation is smaller by one. Therefore, the partial adjustment model is considered. The model indicates that short run elasticities with respect to relative price level is approximately 0.50, whereas in the long run, it equals 1.22. The speed of adjustment is about 0.41, i.e., the actual levels adjust to the desired levels in 2.5 quarters. The null hypothesis H_0**:** b = 1 is rejected at the 5% level. Thus, it is observed that naïve form of PPP does not work. But the partial adjustment framework works. In the case of relative PPP, the variable inflation rate differential is significant in both the frameworks. This indicates that the macro linkage is being established. Although, percentage of variation explained is low (about 17%), but the coefficients have proper signs and significance. The speed of adjustment with which the actual levels of rate of change in exchange rate moves towards the desired levels is approximately one and a half quarters (1/0.72). In none of these regressions, the hypothesis of unit elasticity with respect to relative price levels is accepted at the 5% level of significance. However, unit elasticity null hypothesis is accepted at the 5% level of significance in respect of naïve model implying that PPP holds. Partial adjustment model also works well. The hypothesis of zero intercept and unity as the coefficients of the inflation rate differential are accepted at 5% level of significance. Therefore, relative PPP also holds.

The findings suggest that PPP may not be valid in the presence of external and internal disturbances. Multinational companies should establish consistent pricing for their products in various countries, particularly in India and the United States. Maintaining uniform prices across different markets is crucial to ensuring sustainability. When prices for the same product vary between countries, it creates an opportunity for individuals to purchase the product in the cheaper market and sell it at a higher price in another market, thereby making an arbitrage profit. In practical terms, sometimes foreign exchange traders use PPP to identify potentially overvalued or undervalued currencies. Therefore, policymakers need to carefully look at the specific circumstances, such as the economic situation and internal or external shocks, and exercise caution while framing and implementing monetary policy to reduce the negative effects of exchange rate variations.

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