An Alternative Version of Purchasing Power Parity

Dinçer Afat | Michael Frömmel

Abstract
A vast literature on Purchasing Power Parity (PPP) has evolved and PPP has become the most popular concept in international finance. PPP is applied with various price indices such as consumer price index, wholesale price index, etc. In this article, we introduce a revised version of PPP equation for financial products, which is strongly supported by our panel data analysis.

KEYWORDS
cross-sectional dependence, exchange rate, financial markets, panel data, purchasing power parity

JEL CLASSIFICATION
F31; G15

INTRODUCTION
The literature on the exchange rate is the core part of international finance. This literature has led to various exchange rate models; balance of payments model, purchasing power parity, interest rate parity, monetary models, portfolio balance model, etc. Yet, those models are not very helpful in constructing a valid empirical framework to track the movements of exchange rates or to reveal a stable relationship between the exchange rates and some particular macroeconomic variables.

As Sarno and Taylor (2002, p. 136) state “...although the theory of exchange rate determination has produced a number of plausible models, empirical work on exchange rates has still not produced models that are sufficiently statistically satisfactory to be considered reliable and robust.” Consequently, the search for a better model has been going on and this paper is an outcome of this search; an attempt to revise the most popular exchange rate model that associates exchange rates with price indices, Purchasing Power Parity, by eliminating its shortcomings.

We criticize the applications of PPP that employ the price indices, which cover tangible products, such as the consumer price index (CPI), the wholesale price index (WPI) and etc., since they suffer from a number of deficiencies, which create deviations from PPP, such as transportation cost, tariffs, trade barriers, product differentiation and differences in price index contents across countries. It is also naïve to ignore the huge amount of financial speculation and expect that international trade of tangible products can determine the exchange rates. Thus, PPP should be perceived as a model for intangible products, in other words, financial products since deviations from PPP due to the reasons mentioned above would be accounted when we employ intangible products.

Our contribution to the vast literature on PPP is that we revise the framework of PPP with respect to financial products. Our motivation is similar to that of Akram, Rime, and Sarno (2009). We organize the rest of this article as follows; first, literature outcomes are discussed in brief, then theoretical framework of PPP and its revision are explained. Following an empirical analysis, conclusions are presented.

LITERATURE OUTCOMES
In this article, we do not provide a detailed literature survey since numerous surveys on PPP already exist. We recommend Omay, Emirmahmutoglu, and Hasanov (2018), He, Chou, and Chang (2014), Su et al. (2014), Bahmani-Oskooee, Chang, and Wu (2014), Beckmann (2013), Kruse, Frömmel, Menkhoff, and Sibbertsen (2012), Chang and
According to PPP, exchange rates hinge on overall price levels across countries. This simple model, which acknowledges that common currency prices of similar product bundles are supposed to be equal, is defined as follows:

\[ S_t = \frac{P_t}{P_t^*} \]  

(1)

where:

- \( S \) is the exchange rate in terms of domestic currency price of a unit of foreign currency.
- \( P \) is the price level.
- \( * \) denotes foreign country variable.

or taking natural logarithms;

\[ s_t = \ln(P_t) - \ln(P_t^*) \]  

(2)

Although \( p_t \) does not refer to a particular product type (i.e. tangible or intangible), PPP has always been applied with price indices comprising tangible products since there is a common perception that PPP relies upon tangible products (i.e. goods), consequently intangible products (i.e. financial instruments) are ignored. Neglecting the financial sector is the vital deficiency of PPP since most of the currency transactions stem from financial speculation instead of international trade of goods. Besides the factors; transportation cost, tariffs, trade barriers, product differentiation and differences in price index contents across countries induce persistent deviations from PPP when it is applied with respect to tangible products. Therefore, employing a price index that contains tangible product prices is not necessarily a good way of applying PPP. Thus, we neglect tangible products and focus on intangible (financial) product prices.

We choose government bonds as the representative of financial products to form our model and we do not work with common stock prices. It is because PPP is based on identical/similar products, whereas common stock prices are subject to idiosyncratic (firm specific) risk. Therefore stock index prices are not comparable across countries and it is not possible to find a remedy for this discrepancy. Government bonds are subject to market risk and even though government bonds, too, are not similar/identical across countries, it is possible to accommodate for this discrepancy created by the market risk difference.

However, excluding stock prices does not mean that our analysis neglects stock market. It is because we can acknowledge that there is balance between stock prices and bond prices which is not supposed to be a one-to-one relationship due to time-varying idiosyncratic risk and discount rates. In other words, when we work with government bonds, we indirectly address to stock price movements that are not driven by idiosyncratic risk. Consequently, we can claim that it is possible to refer to common stocks as well by working with bonds. Nevertheless, whether stock prices are covered or not is not a crucial point for our analysis in all respects.

Bond prices are inversely related to the nominal interest rate and we utilize this relationship. Accordingly, we employ the interest rate instead of bond prices since interest rate data is widely available. In fact, it is not possible to use bond prices in the analysis in any case as bonds are not at the same standard with respect to coupon rate, term (number of days) to maturity, etc. Thus, employing interest rate is the process of standardizing bonds and it accounts for the differences in bond properties.

However, replacing bond price with interest rate has a short-coming; convexity, which refers to the non-linear relationship between interest rate and bond price. Yet, we also account for this problem by employing the nominal interest rate to replace the natural logarithm of the price level but not the actual price level. In other words, we utilize the (almost) linear relationship between the interest rate and the natural logarithm of the price level. This linear relationship is not a one-to-one relationship and our analysis does not require a
one-to-one relationship as well, since we allow the coefficients to differ from unity in our model below;

\[ s_t = \beta_0 + \beta_1 I_t + \beta_2 I^*_t + u_t, \quad (3) \]

Expected coefficients: \( \beta_1 < 0 < \beta_2 \)

where:

- \( s \) is log of the nominal exchange rate in units of domestic currency per foreign currency.
- \( I \) is the nominal interest rate.
- \( * \) denotes the variable of the foreign country.

In equation (3), we expect to have a negative coefficient for the domestic nominal interest rate since a rise in the interest rate is associated with a decrease in the bond price and the domestic currency is supposed to appreciate to equalize the common currency prices of bonds across countries. We should mention that (3) is not an application of uncovered interest rate parity (UIRP) although we also employ the nominal interest rate as UIRP does. The framework of our model is different from that of UIRP which is expressed below;

\[ \Delta s^e_{t+k} = I_t - I^*_t \quad (4) \]

where;

\( \Delta s^e_{t+k} \) is the current expectation for the change in exchange rate at time \( t + k \).

UIRP refers to the expected change in the exchange rate whereas (3) pertains to the spot value of the exchange rate. Besides, UIRP specifies positive unity and negative unity coefficients respectively for both the domestic and the foreign interest rates, while the expected coefficient signs in (3) are totally different. Nevertheless, (3) is just the first step of our analysis and it is not the valid final model because it has to be adjusted according to two aspects; first, expected price level and second, market risk.

The critical point about the expected coefficients of the nominal interest rate is that we specify a negative (positive) coefficient for the domestic (foreign) interest rate in (3) but it cannot be attributed to the expected inflation rate. Par value of bonds is fixed, therefore a rise in the expected inflation rate does not increase the par value as well as the coupon payments. Instead, the spot price of bonds decreases to provide higher interest due to the rise in the expected inflation rate since it is certain that the bond price at maturity, the par value, is free from the inflation rate. In other words, the par value will not increase when the inflation rate rises and vice versa. Accordingly, bond price movements due to the expected inflation rate are synthetic for our model. Thus, we should remove the effect of the expected inflation rate on spot prices by replacing the nominal interest rate with the real interest rate (r);

\[ s_t = \beta_0 + \beta_1 r_t + \beta_2 r^*_t + u_t, \quad (5) \]

Expected coefficients: \( \beta_1 < 0 < \beta_2 \)

Using the real interest rate instead of the nominal interest rate can be considered as removing the upper limit of bond prices. As the result, bonds become just like the other products which do not have a fixed future price so that we can conduct the analysis in an unbiased way (the realized inflation rate can be used as a proxy for the expected inflation rate to calculate the real interest rate).

All the discussion on “nominal vs real interest rate” is about using the correct proxy for bond prices. We assert that the real interest rate, but not the nominal interest rate, is the correct proxy for bond prices in our analysis since bonds have a fixed future price which is not affected by the inflation rate. Consequently, the expected inflation affects the spot price of bonds while its future price remains constant, which is opposite of the general case where spot prices are fixed and future prices are determined by inflation. Thus, the effect of the expected inflation on spot bond price is spurious in our analysis. For that reason, we utilize real interest rates as the proxy for bond prices in our revised PPP equation.

We should highlight that we address to the nominal exchange rate while using real interest rates in (5), which is different from the version of UIRP with real rates. UIRP can be modified to utilize real rates by subtracting the expected inflation differential from both sides of (4). Thus, the UIRP version expressed in (6) also employs real interest rates, however it addresses to the expected change in real exchange rate instead of the level of nominal exchange rate that we use. Besides, our model leads to different expected coefficient signs. In other words, (5) and (6) are not similar equations.

\[ \Delta q^e_{t+k} = r_t - r^*_t \quad (6) \]

where;

\( \Delta q^e_{t+k} \) is the current expectation for the change in real exchange rate at time \( t + k \).

There exist many analyses which study the nexus between real exchange rates and real interest rates such as Lothian and Taylor (1996), Bleaney and Laxton (2003), Mark and Moh (2005), Sollis and Wohar (2006), Hoffmann and MacDonald (2009) and Engel (2011, 2016). However, our analysis differs from them since we model the level of nominal exchange rate.
Equation (5) makes the adjustment for the expected inflation rate but not for the market risk. The market risk difference across countries violates the assumption that financial products are perfect substitutes. Nonetheless, a risk premium exists and thus, we use it as an additional variable in the model that relates higher risk with the depreciating currency. We rearrange the model to allow for market risk discrepancies across countries as follows;

\[ s_i = \beta_0 + \beta_1 r_i + \beta_2 \tilde{\lambda}_i + \beta_3 \tilde{\lambda}^*_i + u_i, \]  
(7)

Expected coefficients: \( \beta_1, \beta_4 < 0 < \beta_2, \beta_3 \)

where,

\( \tilde{\lambda} \) is the risk premium.

Equation (7) can also be written with respect to inter-country differences in panel data framework as below;

\[ s_{i,t} = \beta_{0,i} + \beta_{1,i} \tilde{r}_{i,t} + \beta_{2,i} \tilde{\lambda}_{i,t} + u_{i,t}; \quad i = 1, \ldots, N \text{ and } t = 1, \ldots, T; \text{ Expected coefficients: } (\beta_{1,i} < 0 < \beta_{2,i}) \]  
(8)

where;

\( \tilde{r}_{i,t} \) = \( r_{i,t} - \lambda^*_t \) 
\( \tilde{\lambda}_{i,t} \) = \( \lambda - \lambda^*_t \)

Equation (8) and the expected coefficients argue that a rise in domestic real interest rate, which attracts capital due to a decrease in the price of financial products, lets the currency gain value but risk acts like a flaw of the financial products and prevents the financial products to be identical across countries, consequently, risk impedes the effect of real interest rate on the exchange rate.

However, (8) can hold only if the nominal interest rate does not reflect the risk premium; if it does, then (8) would not be supported, e.g. the coefficient of intercountry real interest difference may be positive (the opposite of the expectation) and/or it is very likely to be insignificant. That is because, if nominal interest rate contains a risk premium, then the real interest rate would cover it as well and that is about encompassing two contrary effects. Thus, the inter-country difference of the real interest rate would not have a strong negative link with the exchange rate, since it is diluted by the adverse effect of the risk premium.

In fact, this is also about the efficiency of the government bond market. If it is efficient, the risk premium must be covered by the nominal interest rate. Consequently, favourable result for (8) provides evidence, that the government bond market is not efficient, since risk is not sufficiently reflected in bond prices.

### 4 | EMPIRICAL ANALYSIS

Our analysis covers most of the countries that implement a floating exchange rate regime. Some of them are excluded due to lack of data. For instance, Australia and New Zealand are delisted since CPI, which is used to calculate realized inflation that replaces expected inflation in our research, is available quarterly for those countries while our analysis is built on a monthly data set.

The research covers two balanced panels; panel-1 consists of the U.S. Dollar based 15 bilateral exchange rates and panel-2 comprises 33 cross-currency rates. We prefer to work with those two panels, instead of a single panel, to check whether the results vary with respect to the numeriare/base currency. The data is mainly obtained from the OECD\(^2\) and respective central banks. The real interest rate is calculated by using the realized inflation rate and long term interest rate. We utilize two versions of the real interest rate based on monthly and annual horizons of the realized inflation rate,\(^3\) accordingly we apply the estimations with both horizons to check whether the results are similar. We formulate the two versions as follows;

Annual real interest rate = \( [(1 + I_t) / (1 + (\ln CPI_{t+12} - \ln CPI_t))] - 1 \)

(9)

Monthly real interest rate = \( [(1 + (I_t/12)) / (1 + (\ln CPI_{t+1} - \ln CPI_t))] - 1 \)

(10)

where;

- \( I \) is the nominal interest rate.
- \( CPI \) is the consumer price index.

The risk premium is proxied by the 5-year sovereign credit default swap (CDS) rate in natural logarithm. The research period is 2009:01–2017:11.\(^4\) The availability of CDS data for whole panel members determines the inception date of our research (CDS has not been actively traded until late 2008 for most of the countries). We exclude Canada and Switzerland since CDS data for those countries is available much later than for the other countries. Further information on the two panels and the data sources is provided in the appendix.

To estimate equation (8), we utilize two panel data methods that account for cross-section dependence and slope heterogeneity. One of them is the common correlated effects mean group (CCEMG) estimator by Pesaran (2006). The other one is the augmented mean group (AMG) estimator developed by Eberhardt and Bond (2009) and Eberhardt and Teal (2010).
Considering the standard panel-data model, where \( y_{i,t} \) is the dependent variable and \( x_{i,t} \) is the vector of independent variables, CCEMG can be expressed with the set of equations below.

\[
y_{i,t} = \beta_0 + \beta_{1i} x_{i,t} + u_{i,t}; \quad (i = 1, \ldots, N \text{ and } t = 1, \ldots, T) \tag{11}
\]

\[
x_{i,t} = \theta_i + \psi_i f_t + \epsilon_{i,t} \tag{12}
\]

\[
u_{i,t} = \pi_i + \phi_i f_t + \epsilon_{i,t} \tag{13}
\]

\[
y_{i,t} = a_{0i} + a_{1i} x_{i,t} + \delta_i \bar{y}_t + \eta_i \bar{x}_t + e_{i,t} \tag{14}
\]

where:

- \( \epsilon_{i,t} \) and \( e_{i,t} \) are white-noise residuals.
- \( f_t \) is the common factor(s) of \( x_{i,t} \) and \( u_{i,t} \).
- \( \psi_i \) and \( \phi_i \) are the heterogeneous factor loadings.
- \( \bar{y}_t \) and \( \bar{x}_t \) are cross-section averages.

Pesaran employs cross-section averages \((\bar{y}_t \text{ and } \bar{x}_t)\) in equation (14) to account for the unobserved common factor(s); \( f_t \). The coefficients of the cross-section averages \((\delta_i \text{ and } \eta_i)\) have no meaningful economic interpretation therefore they can be omitted from the analysis output.

An alternative to CCEMG is AMG which is implemented in three steps as explained in Eberhardt (2012); first, a pooled regression model augmented with time dummies is estimated by first difference OLS, and the coefficients on the (differenced) time dummies are collected. They represent an estimated cross-group average of the evolution of unobservable common dynamic process. Second, the group-specific regression model is augmented with this estimated common dynamic process. Finally, the group-specific model parameters are averaged across the panel.

AMG and CCEMG exhibit similar performance with respect to the time-series properties of the unobservable common factors \((f_t)\) in terms of stationarity, structural breaks, etc. Both CCEMG and AMG perform well with non-stationary variables whether they are cointegrated or not (see, Kapetanios, Pesaran, & Yamagata, 2011 and Eberhardt & Bond, 2009 for empirical results). The main difference between AMG and CCEMG is that CCEMG treats the set of unobservable common factors as a nuisance whereas it is a common dynamic process for AMG.

The residuals are supposed to be stationary for a valid estimation. Non-stationary variables may induce violation of this condition, if there is no cointegration. Having cointegration is the proof that the residuals are stationary even though the model contains non-stationary variables. We apply the Pesaran (2007) panel unit root test to the dependent variable (the exchange rate) and see that it is non-stationary for both panels (the details are in the footnote),

which leads us to utilize the Westerlund (2008) panel cointegration method to check the stationarity of the residuals for equation (8). This method requires only the dependent variable to be non-stationary while the regressors are allowed to be stationary or non-stationary. Thus, it is not important whether \( \hat{r} \) and \( \hat{\lambda} \) have unit root.

We perform the Westerlund (2008) test to find out whether panel cointegration exists for the two panels with the two horizons of the real interest rate. Based on the Durbin–Hausman (DH) principle, Westerlund (2008) develops the panel cointegration test, which also accounts for cross-sectional dependence. The presence of significant DHp statistic rejects the null hypothesis; ‘there is no cointegration’, and indicates that cointegration exists for the whole panel. Table 1 provides the panel cointegration results which show that cointegration is supported for most of the cases. Accordingly, we estimate equation-8 with CCEMG and AMG for those cases. The findings are reported in Table 2.

In Table 2, the coefficients of the common dynamic process in the AMG results and the cross-sectional averaged regressors in the CCEMG results are not reported for the
sake of brevity, as they are not crucial for our analysis. According to Table 2, the findings are in favour of our model, since we achieved the expected coefficient signs, which are also significant. This support for equation-8 also implies inefficiency of the government bond market as discussed in section-3.

5 | CONCLUSIONS

In this article, we argue that PPP should not be applied with the prices of tangible products. Using price indices such as CPI and WPI, which are composed of mainly tangible products, suffers from several well-known frictions that distort PPP, such as transportation costs, tariffs, trade barriers, product differentiation and differences in price index composition across countries.

As an alternative, we claim that PPP should be considered as a model for intangible (financial) products and we revise its framework accordingly by using government bonds as a proxy for financial products. Our revised version of PPP eliminates the effect of the mentioned frictions that distort PPP. Besides, our version is much more realistic since exchange rate movements depend mostly on financial transactions instead of international trade of products.

The empirical analysis based on the panel data methods, AMG and CCEMG, provides favourable results for our revised PPP framework. As a secondary outcome, we have also provided evidence that the government bond market is not efficient, since the risk premium is not fully reflected by bond yields.

ENDNOTES

1 Third-country effect is also pertinent to exchange rate modelling. See Berg and Mark (2015) for an analysis.
2 The Organization for Economic Co-operation and Development (OECD)
3 We apply a seasonal adjustment for monthly horizons of real interest rates to account for seasonality.
4 Using realized inflation rate culminates in losing observations. We lose 12 observations for the annual real interest rate. Thus, regressions are applied for the period 2009:01–2016:11. We do not change the period for monthly real interest rate to compare the results even though more data is available.
5 The null hypothesis ‘there is unit root’ is not rejected for the exchange rate in both panels at the 10% significance level. The null hypothesis is rejected for first differences in both panels at the 1% significance level.

REFERENCES


ORCID

*Dinçer Afat* https://orcid.org/0000-0002-9491-5214
APPENDIX - DATA DESCRIPTION

Thomson Reuters-Datastream is the source for CDS data. Cross currency exchange rates are obtained from the respective central banks. The U.S. Dollar based exchange rates and consumer price indices are obtained from the web page of the OECD. Nominal interest rate is mainly proxied by long term interest rate provided by the OECD except for the countries:

- **Brazil**: 3 year government bond (Source: Thomson Reuters-Datastream).
- **Mexico**: 3 year government bond (Source: Central bank of Mexico).
- **Turkey**: Long term interest rate (Source: Eurostat).

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