Testing Purchasing Power Parity: A US-China Case Study And A Cross-Country Analysis

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# Table of Contents

Abstract                                                1

1. Introduction                                         2

2. Methodology                                          5
   2.1 US-China Case Study                               5
   2.2 Cross-Country Analysis                           8

3. Data Analysis                                        9
   3.1 US-China Case Study                              9
       3.11 Relative PPP                                  9
       3.12 Absolute PPP                                 13
   3.12 Cross-Country Analysis                          14

4. Conclusion                                           15

Reference                                               18

Appendix A: Hypothesis Testing for Relative PPP in US-China Case Study  20

Appendix B: Hypothesis Testing for Absolute PPP in US-China Case Study  24

Appendix C: Regression Output for Relative PPP in US-China Case Study  28

Appendix D: Regression Output for Absolute PPP in US-China Case Study  29

Appendix E: Hypothesis Testing for Relative PPP in the Cross-Country Analysis  30

Appendix F: Regression Output for Relative PPP in Cross-Country Analysis  32
Abstract

Purchasing Power Parity is a core international finance principle. It has been viewed as a basis for international comparison of income and expenditures, an equilibrium condition, an efficient arbitrage condition in goods and assets markets, and a theory of exchange rate determination. Results of empirical analysis of PPP can have important implications in exchange rate policy. The concept of PPP has been the subject of numerous such studies but there is some disagreement on its validity. This paper investigates the existence of PPP by means of a US-China case study and a cross-country analysis of 79 countries across different continents with varying economic status. The data rejects the PPP hypothesis under the US-China case study. In contrast, PPP is proven under the cross-country analysis. The failure to prove PPP under the former can have policy implications in light of the perceived undervaluation of the Chinese yuan relative to the US dollar.
1. Introduction

Purchasing power parity (PPP) is an important concept in international finance. It is founded on a microeconomic theory called the law of one price. The law of one price states that an identical commodity, asset or security will have the same price regardless of the location of sale. For example, the price of an identically customized Dell laptop should be exactly the same (in a common currency) whether the computer is selling in the Solomon Islands or in the Czech Republic. This so-called law is based on the concept of arbitrage. Arbitrage is simply the simultaneous buying and selling of the same assets or commodities in different markets to benefit or profit from price discrepancies. Colloquially, it is buying low and selling high to gain a riskless profit. Therefore, it can be said that arbitrage enforces the law of one price. In the context of exchange rates, the law of one price dictates (due to arbitrage) that the home currency value of a good should equal the foreign currency price of that same good times the exchange rate (home currency per unit foreign currency). In other words, a unit of the home currency should have the same purchasing power worldwide. For this to work the law of one price makes four key assumptions. One, there are no transaction costs, such as shipping/transportation costs. Two, there are no barriers of trade, such as tariffs. Three, there is a frictionless market—no monopolies, no oligopolies. Finally, the good must be exactly the same as illustrated in the Dell laptop example. One may easily point out that these assumptions are unrealistic. However, there is consensus among economists that in the long-run these four requirements should not be a problem because over time various regulations change or are introduced, costs can change dramatically and a monopoly can become one among many. Thus, if we look at a set, or basket, of goods (instead of just one item) from a long-
term perspective, the concept of purchasing power parity (based on the law of one price) comes into play.

Swedish economist Gustav Cassel first used PPP in 1918 as the basis for a new set of exchange rates after World War I (Cassel, 1918). Ever since PPP has been used by central banks as a guide in their monetary policy activities to determine exchange rates (Schapiro, 2006). PPP can be used in analyzing a single good like the famed Big Mac Index developed by *The Economist*, but PPP is generally used in looking at a basket of goods in countries. In effect, as an application of the “law”, PPP, in its absolute form, states that the same basket of goods must have the same price in the “home” currency in the “home” nation as well in the foreign nation. Mathematically, this implies that the real exchange rate between two countries is equal to one. Further, this suggests that a change in the nominal exchange rate is a result of the difference in the inflation rates between the home and foreign countries. (See following section.) Thus, a country with a high inflation rate will have a currency that will depreciate. This underlies the notion of undervaluation and overvaluation of currencies. If the nominal exchange rate of a country deviates from what is considered best under PPP principles, that currency is said to be undervalued or overvalued (Cecchetti, 2006). For this reason, PPP plays a core role in international finance. Purchasing power parity has been viewed as a basis for international comparison of income and expenditures, an equilibrium condition, an efficient arbitrage condition in goods and assets markets, and a theory of exchange rate determination. Nevertheless, there are some doubts concerning the validity of the theory of PPP.

PPP has been extensively tested but some of the academic literature proves it while others disprove it. Zurbruegg and Allsopp (2004) in testing PPP in East Asia found
that PPP does exist at different levels of significance when looking at the relationship of consumer prices and exchange rates. Serletis and Gogas (2004) using quarterly data on 21 OECD countries found weak evidence consistent with PPP. Alba and Papell (2007) in their investigation of PPP using advanced econometric methodologies involving 84 developed and developing countries found that PPP held for European and Latin American countries but did not for African and Asian ones. Shively (2001) concluded that PPP is valid for countries with low inflation and low trade barriers. Yazgan (2003) proved the existence of PPP in a high inflation nation in his case study of Turkey. Robertson et al. (2009) found strong evidence in support of PPP between the U.S. and Mexico due to favorable trade relations between the two nations and the flexibility of the exchange rate. According to Xu (2003) the PPP hypothesis is rejected when using CPI data. Baharumshah and Ariff (2002) presented findings that failed to support the PPP hypothesis in five South East Asian countries.

This paper tests the PPP concept by means of a two case studies. The first is a US-China case study. China is growing to super-power status by some accounts. There is even some talk of a G2. China plays an important role in international finance in its capacity as a behemoth of a trading partner. According to the World Trade Organization (WTO), China ranks as number 1 and number 3 in world exports and imports respectively. Specifically, China serves as a major trading partner of the US. As per WTO, the US is the number 2 destination of Chinese goods after the European Union. In addition to its trading relations, China has invested a high amount of capital in the US. According to the US Treasury, China owns US$798.9 billion worth of US Treasury securities, the largest sovereign nation holder to the US. In light of the significant
economic relations between US and China, there has been controversy over the so-called intentional undervaluation of the yuan (or, renminbi) in relation to the US dollar. Eckaus (2004) provided some evidence that the China is not intentionally undervaluing their currency as is widely believed. Tatom (2007) argues that the yuan is correctly valued for the long term. As mentioned earlier, underneath the notion of a currency being undervalued or overvalued is the concept of purchasing power parity. Hence, this paper investigates the existence of PPP in the US-China context. The second case study is a cross-country analysis involving 79 countries of different economic conditions from multiple continents. The theory implies that PPP should exist regardless of “type” of nation.

This paper is organized as follows. The following section discusses the methodology involved in investigating for PPP. The third section provides data analysis on the data collected. The final section concludes with results of analysis and examines policy implications due to these results.

2. Methodology

2.1 U.S. - China Case Study

Purchasing power parity (PPP) serves as the key underlying feature in any investigation of the long run movement of exchange rates (Zurbruegg and Allsopp, 2004). PPP states that

\[ q_t = \frac{E_t P_t^*}{P_t} \]

(1)

where \( P_t \) denotes the price level (price index) of the home country, \( P_t^* \) denotes the
foreign price level and $E_t$ the nominal exchange rate (the home currency per unit of foreign currency), $q_t$ denotes the real exchange rate and $t$ denotes a particular point in time. According to the PPP principle, the real exchange rate should equal to one, hence, $q_t$ equals to one. Equation 1 can be re-written as

$$E_t = P_t/P_t^*$$

(2)

Therefore, any percentage change in nominal exchange equals to the difference between the percentage change of the domestic price level (price index) and the percentage change of the foreign price level.

$$\%\Delta E = \%\Delta P - \%\Delta P^*$$

(3)

Equation 3 refers to the “relative version” of PPP, which relates exchange rate change with the inflation rates (change in price levels) of the two countries. Thus, this paper tests “relative PPP” by estimating

$$\%\Delta E = \beta_0 + \beta_1\%\Delta P - \beta_2\%\Delta P^* + u$$

(4)

where $\beta_0$, $\beta_1$ and $\beta_2$ denote the arbitrary constant term (the intercept) and the coefficients of the regressors; $u$ is the error (residual) term. This is a linear model; thus, the method of ordinary least squares (OLS) is employed. Equation 4 involves a multivariable regression analysis. This paper tests “Relative PPP” by using bivariate regression analysis as well by estimating the following equation.
\[
\% \Delta E = \beta_0 + \beta_1(\% \Delta P - \% \Delta P^*) + u
\]

(5)

In addition, to investigating for relative PPP, this paper tests PPP in its “absolute version”. By logarithmic transformation of Equation 2, we arrive at the linear relationship

\[
e_t = p_t - p_t^*
\]

(6)

where, \(e_t\) equals \(\ln(E_t)\) and refers to the nominal exchange rate after taking the natural log, \(p_t\) equals \(\ln(P_t)\) and refers to the price level (price index) of the home country after the transformation and \(p_t^*\) equals \(\ln(P_t^*)\) and denotes the price index of the foreign country after the transformation.

Using bivariate and multivariate regression analyses via the method of ordinary least squares (OLS), Equation 6 is estimated by the two linear models:

\[
e_t = \beta_0 + \beta_1(p_t - p_t^*) + u
\]

(7)

\[
e_t = \beta_0 + \beta_1 p_t - \beta_2 p_t^* + u
\]

(8)

PPP theory, based on the microeconomic law of one price, states that real exchange rate is equal to one. For every change of the inflation rate of either country, \textit{ceteris paribus}, there should be a corresponding change of the same magnitude and sign in the nominal exchange rate. See Equation 3. Therefore, the constant term (\(\beta_0\)) should be equal to zero, the coefficient of the regressor in the bivariate analyses and the coefficients of the two regressors in the multivariate analyses should equal one. Thus, this paper tests the
hypotheses: $\beta_0 = 0$, $\beta_1 = 1$, and $\beta_2 = 1$. In addition, the statistical significance of the regressor(s) is tested. Failure of rejection of the various hypotheses would indicate that the theory of PPP holds up for the particular data being analyzed.

2.2 Cross-Country Analysis

Under the monetary approach of exchange rate determination PPP (in its relative form) states, as in Equation 3, the rate of change of the nominal exchange rate between two countries is equal to the difference of the rates of change of the price levels of the two nations. This rate of change in the exchange rate can be called the rate of depreciation of the nominal exchange rate (per year relative to the US$). The difference in the rates of change in the price levels can be referred to as the inflation differential since the rate of change in the price level (CPI) is the inflation rate. In light of this, we have the following equation:

$$\%\Delta E = \Pi^* - \Pi$$  \hspace{1cm} (9)

where, $\%\Delta E$ refers to the rate of depreciation of the nominal exchange rate expressed in per U.S. dollar terms, $\Pi$ refers to the inflation rate of the United States and $\Pi^*$ refers to the inflation rate of the foreign country. The difference in the two inflation rates is called the inflation differential. Equation 9 serves as the basis for the OLS linear model for this paper’s country analysis.

$$\%\Delta E = \beta_0 + \beta_1(\Pi^* - \Pi) + u$$  \hspace{1cm} (10)

$\%\Delta E$, $\Pi$, and $\Pi^*$ are the change of nominal exchange rate and the inflation rates, respectively, over the long run. If PPP holds in the long run, the theory predicts that the $\beta_0$ would be equal to 0 and $\beta_1$ would equal 1. A change in the inflation differential would
result in a corresponding change in magnitude and sign in the rate of depreciation.

3. Data Analysis

3.1 US-China Study

To test for PPP in this paper’s US-China case study, data on the price indices (price levels) of the two countries and on the nominal exchange is collected. Monthly data from January 1994 to August 2009 is collected on all three variables. The CPI data is taken from the Organization for Economic Co-operation and Development (OECD). The data on nominal exchange rate is taken from the International Financial Statistics of the International Monetary Fund (IMF). The nominal exchange rate found was in yuan/USD form so the inverse was taken to get USD/yuan since by common practice the nominal exchange rate is described as the home currency per unit of foreign currency in PPP theory. Here the US is the home country.

3.11 Relative PPP Data

Based on Equations 4 and 5, to test relative PPP, the percentage changes in the USD/yuan exchange and in CPIs for US and China are calculated for each month. For bivariate regression analysis, the percent change of China’s price index is subtracted from the US’s price index. Total observations in the sample for Relative PPP are 187. Table 1 shows the description of the data variables.

There is skewness in the dataset. The data for %ΔP* and %ΔE are both right-skewed with skewness values greater that 0. Further, %ΔE is highly skewed since the absolute value of its statistic (2.9007) is greater than 1. %ΔP and %Δ(P-P*) data are left-skewed. Further, %ΔP is highly skewed since the absolute value of its statistic (1.3423) is
greater than 1. However, when rounded to four decimal places (as Table 1 shows) the mean and the median of \( \%\Delta P \) are both equal to 0.0021. In addition, the ranges are fairly small. The data distribution data for all four variables is “fat-tailed”, or relatively peaked as compared to a normal distribution. Each has a kurtosis greater than 0. Three of the variables have a mode of 0; logically, this means that at least twice there was no change in the particular variables at two separate points in time.

As explained in the previous section, to test for PPP, this paper tests if the following hypotheses hold, since based on the theory there should be a one-for-one relationship for a change in one of the inflation rates (change in price index) and the change in the nominal exchange rate, ceteris paribus. Based on the relative models described in the previous section the “two-sided” hypotheses: \( H_0 = \beta_0 = 0 \); \( H_0 = \beta_1 = 1 \) (for the bivariate model); for the multivariate model \( H_0 = \beta_2 = 1 \) is tested additionally. Statistical significance of regressor(s) is checked by setting \( H_0 = \beta_1 ( = \beta_2 ) = 0 \). Significance level of 5% is used. See Appendix A for actual tests.

The data rejects the null hypotheses that state that the intercept and slope coefficient(s) should equal to zero and one respectively for the bivariate and multivariate models. Using the P-value approach and the critical value approach for the bivariate model, the conditions for rejection are met. For the P-value approach, the calculated P-values are less than the significance level. For the critical value approach the absolute values of the t-statistic are greater than the critical values. Only the P-value approach is employed for multivariate analysis. The coefficient(s) of the regressor(s) are statistically significant.
### Table 1: Descriptive Statistics for Variables in analyzing Relative PPP in US-China Case Study

<table>
<thead>
<tr>
<th></th>
<th>%ΔE</th>
<th>%ΔP</th>
<th>%ΔP*</th>
<th>%Δ(P-P*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.0013</td>
<td>0.0021</td>
<td>0.0028</td>
<td>-0.0007</td>
</tr>
<tr>
<td>Standard Error</td>
<td>0.0002</td>
<td>0.0003</td>
<td>0.0007</td>
<td>0.0007</td>
</tr>
<tr>
<td>Median</td>
<td>0.0000</td>
<td>0.0021</td>
<td>0.0010</td>
<td>-0.0009</td>
</tr>
<tr>
<td>Mode</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>#N/A</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.0030</td>
<td>0.0036</td>
<td>0.0095</td>
<td>0.0097</td>
</tr>
<tr>
<td>Sample Variance</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0001</td>
<td>0.0001</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>9.0816</td>
<td>6.6663</td>
<td>1.1718</td>
<td>0.6767</td>
</tr>
<tr>
<td>Skewness</td>
<td>2.9007</td>
<td>-1.3423</td>
<td>0.8274</td>
<td>-0.5012</td>
</tr>
<tr>
<td>Range</td>
<td>0.0192</td>
<td>0.0314</td>
<td>0.0525</td>
<td>0.0579</td>
</tr>
<tr>
<td>Minimum</td>
<td>-0.0020</td>
<td>-0.0192</td>
<td>-0.0140</td>
<td>-0.0358</td>
</tr>
<tr>
<td>Maximum</td>
<td>0.0171</td>
<td>0.0122</td>
<td>0.0385</td>
<td>0.0221</td>
</tr>
<tr>
<td>Sum</td>
<td>0.2426</td>
<td>0.3912</td>
<td>0.5268</td>
<td>-0.1356</td>
</tr>
<tr>
<td>Count</td>
<td>187</td>
<td>187</td>
<td>187</td>
<td>187</td>
</tr>
<tr>
<td>Confidence Level(95.0%)</td>
<td>0.0004</td>
<td>0.0005</td>
<td>0.0014</td>
<td>0.0014</td>
</tr>
</tbody>
</table>

Descriptive Statistics of the dependent variable, rate of change of the exchange rate (per foreign country), the regressors, rate of change of price levels of the U.S. and foreign country (under the multivariate analysis) and the single regressor, differential of rate of change of price levels (under the bivariate analysis).

**Source:** OECD and IMF

### Table 2: Descriptive Statistics for Variables in Analyzing Absolute PPP in US-China Case Study

<table>
<thead>
<tr>
<th></th>
<th>e at time t</th>
<th>p at time t</th>
<th>p* at time t</th>
<th>p - p*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>-2.0893</td>
<td>4.5139</td>
<td>4.5601</td>
<td>-0.0462</td>
</tr>
<tr>
<td>Standard Error</td>
<td>0.0044</td>
<td>0.0085</td>
<td>0.0073</td>
<td>0.0043</td>
</tr>
<tr>
<td>Median</td>
<td>-2.1135</td>
<td>4.5108</td>
<td>4.5524</td>
<td>-0.0291</td>
</tr>
<tr>
<td>Mode</td>
<td>-2.1135</td>
<td>4.4439</td>
<td>4.5436</td>
<td>#N/A</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.0607</td>
<td>0.1159</td>
<td>0.0995</td>
<td>0.0594</td>
</tr>
<tr>
<td>Sample Variance</td>
<td>0.0037</td>
<td>0.0134</td>
<td>0.0099</td>
<td>0.0035</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>2.5133</td>
<td>-1.1442</td>
<td>2.5039</td>
<td>-0.4873</td>
</tr>
<tr>
<td>Skewness</td>
<td>1.8998</td>
<td>0.1124</td>
<td>-0.9697</td>
<td>-0.2886</td>
</tr>
<tr>
<td>Range</td>
<td>0.2431</td>
<td>0.4085</td>
<td>0.5419</td>
<td>0.2807</td>
</tr>
<tr>
<td>Minimum</td>
<td>-2.1637</td>
<td>4.3157</td>
<td>4.1974</td>
<td>-0.1625</td>
</tr>
<tr>
<td>Maximum</td>
<td>-1.9206</td>
<td>4.7241</td>
<td>4.7394</td>
<td>0.1182</td>
</tr>
<tr>
<td>Sum</td>
<td>-392.7878</td>
<td>848.6204</td>
<td>857.3056</td>
<td>-8.6853</td>
</tr>
<tr>
<td>Count</td>
<td>188.0000</td>
<td>188.0000</td>
<td>188.0000</td>
<td>188.0000</td>
</tr>
<tr>
<td>Confidence Level(95.0%)</td>
<td>0.0087</td>
<td>0.0167</td>
<td>0.0143</td>
<td>0.0086</td>
</tr>
</tbody>
</table>

Descriptive Statistics of the dependent variable, exchange rate (per foreign country), the regressors, price levels of the U.S. and foreign country (under the multivariate analysis) and the single regressor, price level differential (under the bivariate analysis) after undergoing logarithmic transformation.
This scatter plot shows the relationship between the rate of exchange-rate depreciation against the U.S. dollar and the inflation differential against the United States over the long run.  
*Source: World Development Indicators, World Bank.*
3.12 Absolute PPP Data

Based on equations 7 and 8, the data of the CPI of China and US and the nominal exchange undergo logarithmic transformation. For bivariate regression analysis the regressor is the differential between the American CPI and the Chinese CPI (after taking the logarithm). Total observations in the sample of Absolute PPP are 188 (one more than in the Relative PPP sample since there was no actual percent change calculation here). Table 2 shows the description of the data.

There is skewness in the dataset. The data on the variables $e_t$ and $p_t$ are right-skewed, while the data on $p_t^*$ and $(p_t-p_t^*)$ are left-skewed. Further, $e_t$ is highly skewed since the absolute value of its statistic (1.8998) is greater than 1. However, the ranges are fairly small. The data on $e_t$ and $p_t^*$ have kurtosis greater than 0, they have distributions that are “fat-tailed”, or relatively peaked as compared to a normal distribution.

Similar in the test of relative PPP, with hypothesis testing of absolute PPP, we have the following “two-sided” hypotheses: $H_0 = \beta_0 = 0$; $H_0 = \beta_1 = 1$ (for the bivariate model); for the multivariate model $H_0 = \beta_2 = 1$ is tested additionally. Statistical significance of regressor(s) is checked by setting $H_0 = \beta_1 (\beta_2) = 0$. Significance level of 5% is used. See Appendix B for actual tests.

The data rejects the null hypotheses that state that the intercept and slope coefficient(s) should equal to zero and one respectively for the bivariate and multivariate models. Using the P-value approach for both models (along with the critical value approach for bivariate), the conditions for rejection are met. The calculated P-values are less than the significance level. For the critical value approach the absolute values of the t-statistic are greater than the critical values. The coefficient(s) of the regressor(s) is (are)
statistically significant.

The data in the US-China case study does not support the PPP theory. Both multivariate and bivariate analyses of Absolute and Relative PPP fail to support the one-to-one relationship between the difference of the inflation rates of both countries and the nominal exchange (measured in USD/yuan).

3.2 Cross-Country Analysis

To test (relative) PPP under the cross-country analysis data on the nominal exchange rate (per U.S. dollar) and the price levels (CPIs) of 79 countries are collected from the World Bank’s World Development Indicators. The countries are of various economic conditions and are from multiple continents. (However some do not belong to a continent, such as Trinidad and Tobago and Papua New Guinea.) For each variable, data is collected for 1980 and 2008. The rate of depreciation of the exchange rate over the block period of 1980 to 2008 is calculated. Likewise, the rates of change in CPI (the inflation rate) of the two countries are calculated over the same period. The inflation rate of the United States is subtracted from the inflation rate of each of the countries in the sample to obtain the various values for the independent variable (inflation differential).

In order for PPP to hold in the cross-country analysis, similar to the testing PPP in the US-China case study, the regressor (inflation differential) must equal the rate of depreciation (the dependent variable). This implies that the slope of the regression equation should equal 1 and the intercept (the value of the rate of depreciation when the inflation differential equals 0) should equal 0. Hence, for “two-sided” hypothesis testing, we set $H_0: \beta_0 = 0$ and $H_a \neq 0$ for the intercept and $H_1: \beta_1 = 1$ and $H_a: \beta_1 \neq 1$ for the slope. The critical value and p-value approaches are employed at a significance level of
5%. See Appendix E for actual tests.

The data rejects the null hypothesis that the intercept is equal to zero. Under the P-value approach, the P-value is less than 5% and under the critical value approach the t-statistic is greater than the critical value, hence the rejection. The intercept is said to be statistically significant. However, the data fails to reject the hypothesis that the slope is equal to one. The conditions under both approaches for failure to reject the null hypothesis are met. Therefore, as the theory of relative PPP suggests, the inflation differential equals the rate of depreciation for the 79 countries (counting the U.S.) in the sample. Since the regressor equals the dependent variable, we can show this graphically via a 45 degree angle trend line in the scatter plots as seen in Figure 1. In the diagram, the trend line is approximately 45 degrees since the intercept turns out to not be equal to zero as previously mentioned. To make the diagram more visually presentable, only 72 “points” of the sample of 79.

In sum, the data in the cross-country analysis supports PPP. There is the one-to-one relationship between the inflation differential (relative the US) and the rate of depreciation (relative to the US$). Over the long run, in this case from 1980 to 2008, PPP holds.

4. Conclusion

Based on the academic literature, there is some disagreement on the validity of PPP, a key macroeconomic principle. This paper investigates whether the theory of PPP holds up in a US-China case study and a cross-country analysis. The method employed is the method of ordinary least squares (OLS). For the US-China case study monthly data is
collected from January 1994 to August 2009. The data does not support the PPP theory in its absolute or relative form. PPP theory implies that there should be a one-for-one relationship between the differential in changes in the inflation rates of US and China and the nominal exchange rate (measured in USD/yuan). However, the data analyzed rejects this. For the cross-country analysis, data is collected of 79 diverse nations from 1980 to 2008. In contrast to the US-China case-study, PPP is proven in the long-run.

The methodology used does have its shortcomings. There are more advanced methodologies that give a more accurate test of PPP (See Serletis and Gogas, 2004). In addition, there may be factors (in the residual term) that may have affected or obscured the lack of existence of PPP in the US-China case study. These factors can include GDP growth rate, relative openness to trade during the time period selected and difference in exchange rate policy (Alba and Papell, 2007).

Specifically for the US-China case study, the results of this test can have implications in exchange rate policy between the two countries in light of the extensive trade between them. The failure of this paper’s study to find evidence of PPP in the case study may suggest to some that the yuan-US$ exchange rate is not at its “right” value. However, more rigorous analysis may be needed to validate or invalidate the merit of the argument that the yuan is undervalued and that the Chinese government needs to take steps to ensure its appreciation.

For the cross-country analysis, as the theory of relative PPP suggests, the inflation differential of the countries in the sample (relative to the US) equals the rate of depreciation (relative to the US$). The contrast in results of this analysis as compared in the two country case study may suggest that PPP may be more readily proven in
empirical investigations that involve a large sample size of countries. In addition, the results of the analysis further illustrate the fact that PPP is a model that can only be proven over time.
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Appendix A: Hypothesis Testing for Relative PPP in US-China Case Study

Bivariate Regression Analysis of Relative PPP

A.1 Testing for intercept = 0 and slope = 1 at a significance level of 5% via the P-VALUE Approach

\[
\%\Delta E_t = \beta_0 + \beta_1(\%\Delta P_t - \%\Delta P_t^*) + u
\]

\[
\%\Delta E_t = \hat{b}_0 + \hat{b}_1(\%\Delta P_t - \%\Delta P_t^*) + u_t
\]

*****

\[H_0: \beta_0 = 0\]

\[H_a: \beta_0 \neq 0\]

\[t^* = \frac{(b_0 - \beta_0)}{S_{b_0}}\]

\[= \frac{(0.001271564 - 0)}{0.00022176}\]

\[= 5.7340442\]

\[P = TDIST(|t^*|, n - 2, 2) = TDIST (5.7340442, 185, 2) = 3.932E-08 \approx 0\]

\[P < \alpha, reject H_0\]

The data rejects the hypothesis that the constant (intercept) is equal to 0 at a 5% significance level.

*****

\[H_0: \beta_1 = 1\]

\[H_a: \beta_1 \neq 1\]

\[t^* = \frac{(b_1 - \beta_1)}{S_{b_1}}\]

\[= \frac{(-0.035383806 - 1)}{0.02287805}\]

\[= -45.25664582\]

\[P = TDIST(|t^*|, n - 2, 2) = TDIST (45.25664582, 185, 2) = 5.3035E-102 \approx 0\]

\[P < \alpha, reject H_0\]

The data rejects the hypothesis that the coefficient of the differential in American and Chinese inflation rates is a unit (i.e., one) at a 5% significance level.
Bivariate Regression Analysis of Relative PPP

A.2 Testing for intercept = 0 and slope = 1 at a significance level of 5% via the CRITICAL VALUE Approach

\[ \%\Delta E_t = \beta_0 + \beta_1 (\%\Delta P_t - \%\Delta P^*_t) + u \]
\[ \%\Delta \hat{E}_t = \hat{b}_0 + \hat{b}_1 (\%\Delta P_t - \%\Delta P^*_t) + u_t \]

******

\( H_0: \beta_0 = 0 \)
\( H_a: \beta_0 \neq 0 \)

\[ t^* = \frac{b_0 - \beta_0}{S_{b_0}} \]
\[ = \frac{(0.001271564 - 0)}{0.00022176} \]
\[ = 5.7340442 \]
\[ c = TINV (\alpha, n - 2,) = TINV (0.05, 185) = 1.972869904 \]
\[ |t^*| > c, \text{ hence reject } H_0 \]

The data rejects the hypothesis that the constant (intercept) is equal to 0 at a 5% significance level.

******

\( H_0: \beta_1 = 1 \)
\( H_a: \beta_1 \neq 1 \)

\[ t^* = \frac{b_1 - \beta_1}{S_{b_1}} \]
\[ = \frac{(-0.035383806 - 1)}{0.02287805} \]
\[ = -45.25664582 \]
\[ c = TINV (\alpha, n - 2,) = TINV (0.05, 185) = 1.972869904 \]
\[ |t^*| > c, \text{ hence reject } H_0 \]

The data rejects the hypothesis that the coefficient of the differential in American and Chinese inflation rates is a unit at a 5% significance level.
Multivariate Regression Analysis of Relative PPP

A.3 Testing for the intercept = 0 and statistical significance of slopes at a significance level of 5% via P-VALUE Approach

\[ \%\Delta E_t = \beta_0 + \beta_1 \%\Delta P_t - \beta_2 \%\Delta P^*_t + u \]  (based on PPP theory)

\[ \%\hat{\Delta E}_t = \hat{\beta}_0 + \hat{\beta}_1 \%\Delta P_t - \hat{\beta}_2 \%\Delta P^*_t + u_t \]  (based on PPP theory)

********

\[ H_0: \beta_0 = 0 \]
\[ H_a: \beta_0 \neq 0 \]

\[ t^* = (b_0 - \beta_0) / S_{b_0} \]
\[ = (0.000825447 - 0) / 0.000252668 \]
\[ = 3.266917606 \]

\[ P = \text{TDIST}(|t^*|, n - 2, 2) = \text{TDIST} (3.266917606, 185, 2) = 0.001297085 \]

\[ P < \alpha \], reject \( H_0 \)

The data rejects the hypothesis that the constant (intercept) is equal to 0 at a 5% significance level.

********

\[ H_0: \beta_1 = \beta_2 = 0 \]
\[ H_a: \text{at least one of } \beta_1 \text{ and } \beta_2 \neq 0 \]

\[ F = 7.013840089 \]

\[ P \text{ (or, Significance F) } = 0.001159997 \]

\[ P < \alpha \], reject \( H_0 \)

At a 5% significance level, the two regressors are statistically significant.
Multivariate Regression Analysis of Relative PPP.

A.4 Testing if slope coefficients equal to 1 at a significance level of 5% via P-VALUE Approach

%ΔE_i = β_0 + β_1 %ΔP_i^* - β_2 %ΔP_i - u (based on PPP theory)

%ΔE_i = \hat{β}_0 + \hat{β}_1 %ΔP_i - \hat{β}_2 %ΔP_i^* + \epsilon_i (based on PPP theory)

******

H_0: β_1 = 1
H_a: β_1 ≠ 1

\[ t^* = (b_1 - β_1) / S_{b_1} \]
\[ = (0.1523 - 1) / 0.0597 \]
\[ = -14.1993 \]

\[ P = TDIST (|t^*|, n - 2, 2) = TDIST (14.1993, 185, 2) = 1.9798E-31 \approx 0 \]

\( P < α \), reject \( H_0 \)

The data rejects the hypothesis that the coefficient of the percent change in US CPI is equal to 1 at a 5% significance level.

******

H_0: β_2 = 1
H_a: β_2 ≠ 1

\[ t^* = (b_2 - β_2) / S_{b_2} \]
\[ = (0.0544 - 1) / 0.02295 \]
\[ = -41.2046 \]

\[ P = TDIST (|t^*|, n - 2, 2) = TDIST (41.2046, 185, 2) = 3.8332E-95 \approx 0 \]

\( P < α \), reject \( H_0 \)

The data rejects the hypothesis that the coefficient of the percent change in China CPI is equal to 1 at a 5% significance level.
Appendix B: Hypothesis Testing for Absolute PPP in US-China Case Study

Bivariate Regression Analysis of Absolute PPP

B.1 Testing for the intercept = 0 and slope = 1 at a significance level of 5% via CRITICAL VALUE Approach

\[ e_i = \beta_0 + \beta_1 (p_i - p_{i}^*) + u_i \]
\[ \hat{e}_i = \hat{\beta}_0 + \hat{\beta}_1 (P_i - P_{i}^*) + u_i \]

*****

\[ H_0: \beta_0 = 0 \]
\[ H_a: \beta_0 \neq 0 \]
\[ t^* = \frac{b_0 - \beta_0}{S_{b_0}} \]
\[ = \frac{-2.0801804 - 0}{0.005520911} \]
\[ = -376.782103 \]
\[ c = TINV (\alpha, n - 2,) = TINV (0.05, 186) = 1.972800071 \]
\[ |t^*| > c, \text{ hence reject } H_0 \]

The data rejects the hypothesis that the constant (intercept) is equal to 0 at a 5% significance level.

*****

\[ H_0: \beta_1 = 1 \]
\[ H_a: \beta_1 \neq 1 \]
\[ t^* = \frac{b_1 - \beta_1}{S_{b_1}} \]
\[ = \frac{0.19733145 - 1}{0.07346693} \]
\[ = -10.92557631 \]
\[ c = TINV (\alpha, n - 2,) = TINV (0.05, 186) = 1.972800071 \]
\[ |t^*| > c, \text{ hence reject } H_0 \]

The data rejects the hypothesis that the coefficient of the differential in American and Chinese inflation rates is a unit at a 5% significance level.
Bivariate Regression Analysis of Absolute PPP

B. 2 Testing for the intercept = 0 and slope = 1 at a significance level of 5% via P-VALUE Approach

\[ e_t = \beta_0 + \beta_1 (p_t - p_t^*) + u \]

\[ \hat{e}_t = \hat{b}_0 + \hat{b}_1 (p_t - p_t^*) + u_t \]

********

\( H_0: \beta_0 = 0 \)

\( H_a: \beta_0 \neq 0 \)

\[ t^* = \frac{(b_0 - \beta_0)}{S_{b_0}} \]

\[ = \frac{-2.0801804 - 0}{0.005520911} \]

\[ = -376.782103 \]

\[ P = \text{TDIST} (|t^*|, n - 2, 2) = \text{TDIST} (376.782103, 186, 2) = 4.2E-270 \approx 0 \]

\( P < \alpha, \text{ reject } H_0 \)

The data rejects the hypothesis that the constant (intercept) is equal to 0 at a 5% significance level.

********

\( H_0: \beta_1 = 1 \)

\( H_a: \beta_1 \neq 1 \)

\[ t^* = \frac{(b_1 - \beta_1)}{S_{b_1}} \]

\[ = \frac{0.19733145 - 1}{0.07346693} \]

\[ = -10.92557631 \]

\[ P = \text{TDIST} (|t^*|, n - 2, 2) = \text{TDIST} (10.92557631, 186, 2) = 8.77255E-22 \approx 0 \]

\( P < \alpha, \text{ reject } H_0 \)

The data rejects the hypothesis that the coefficient of the differential in American and Chinese inflation rates is a unit at a 5% significance level.
Multivariate Regression Analysis of Absolute PPP

B.3 Testing for the intercept = 0 and statistical significance of slopes at a significance level of 5% via P-VALUE Approach

\[ e_t = \beta_0 + \beta_1 P_t - \beta_2 P_t^* + u \] (based on PPP theory)

\[ \hat{e}_t = \hat{\beta}_0 + \hat{\beta}_1 P_t - \hat{\beta}_2 P_t^* + u_t \] (based on PPP theory)

\[ t* = \left( b_0 - \beta_0 \right) / \sigma_b \]

\[ = -4.263065567 / 0.120324561 \]

\[ = -35.42972048 \]

\[ P = \text{TDIST} (|t*|, n-2, 2) = \text{TDIST} (35.42972048, 186, 2) = 1.25253E-84 \approx 0 \]

\[ P < \alpha, \text{ reject } H_0 \]

The data rejects the hypothesis that the constant (intercept) is equal to 0 at a 5% significance level.

\[ t* = \left( b_0 - \beta_0 \right) / \sigma_b \]

\[ = -4.263065567 / 0.120324561 \]

\[ = -35.42972048 \]

\[ P = \text{TDIST} (|t*|, n-2, 2) = \text{TDIST} (35.42972048, 186, 2) = 1.25253E-84 \approx 0 \]

\[ P < \alpha, \text{ reject } H_0 \]

At a 5% significance level, the two regressors are statistically significant.

\[ H_0: \beta_1 = \beta_2 = 0 \]

\[ H_a: \text{at least one of } \beta_1 \text{ and } \beta_2 \neq 0 \]

\[ F = 174.6606293 \]

\[ P \text{ (or, } \text{Significance } F) = 2.4641E-43 \approx 0 \]

\[ P < \alpha, \text{ reject } H_0 \]

At a 5% significance level, the two regressors are statistically significant.
Multivariate Regression Analysis of Absolute PPP

B.4 Testing if slope coefficients equal to 1 at a significance level of 5% via P-VALUE Approach

\[ e_i = \beta_0 + \beta_1 p_i - \beta_2 p_i^* + u \]  
(based on PPP theory)

\[ \hat{e}_i = \hat{\beta}_0 + \hat{\beta}_1 p_i - \hat{\beta}_2 p_i^* + u_i \]  
(based on PPP theory)

******

\[ H_0: \beta_1 = 1 \]
\[ H_a: \beta_1 \neq 1 \]

\[ t* = (b_1 - \beta_1) / S_{b_1} \]
\[ = (0.1977 - 1) / 0.0442 \]
\[ = -18.16045 \]

\[ P = \text{TDIST} (|t*|, n - 2, 2) = \text{TDIST} (18.16045, 186, 2) = 4.6367E-43 \approx 0 \]

\[ P < \alpha, \text{ reject } H_0 \]

The data rejects the hypothesis that the first slope coefficient is equal to 1 at a 5% significance level.

******

\[ H_0: \beta_2 = 1 \]
\[ H_a: \beta_2 \neq 1 \]

\[ t* = (b_1 - \beta_1) / S_{b_1} \]
\[ = (0.28099 - 1) / 0.05144 \]
\[ = -13.97679 \]

\[ P = \text{TDIST} (|t*|, n - 2, 2) = \text{TDIST} (13.97679, 186, 2) = 8.15093E-31 \approx 0 \]

\[ P < \alpha, \text{ reject } H_0 \]

The data rejects the hypothesis that the second slope coefficient is equal to 1 at a 5% significance level.
## Appendix C: Regression Output for Relative PPP in US-China Case Study

### Bivariate Model

**SUMMARY OUTPUT**

<table>
<thead>
<tr>
<th>Regression Statistics</th>
<th></th>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
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<td>Adjusted R Square</td>
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<tr>
<td>Standard Error</td>
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<tr>
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<table>
<thead>
<tr>
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<th>Significance F</th>
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<tbody>
<tr>
<td>Regression</td>
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<td>2.1874E-05</td>
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<td>Residual</td>
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<td>0.001691725</td>
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<td>Total</td>
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<td>0.001713599</td>
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<thead>
<tr>
<th>Coefficients</th>
<th>Standard Error</th>
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<th>P-value</th>
<th>Lower 95%</th>
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<tbody>
<tr>
<td>Intercept</td>
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<td>3.93201E-08</td>
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<tr>
<td>( %\Delta(P-P^*) )</td>
<td>-0.035383806</td>
<td>0.02287805</td>
<td>-1.54662688</td>
<td>0.12366217</td>
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### Multivariate Model

**SUMMARY OUTPUT**

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<td>Observations</td>
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<th>Significance F</th>
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<td>Total</td>
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<th>P-value</th>
<th>Lower 95%</th>
</tr>
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<tbody>
<tr>
<td>Intercept</td>
<td>0.000825447</td>
<td>0.000252668</td>
<td>3.266917606</td>
<td>0.001297085</td>
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<tr>
<td>( %\Delta P )</td>
<td>0.152296616</td>
<td>0.05965134</td>
<td>2.553113068</td>
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<tr>
<td>( %\Delta P^* )</td>
<td>0.054380095</td>
<td>0.022949371</td>
<td>2.369567941</td>
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Appendix D: Regression Output for Absolute PPP in US-China Case Study

**Bivariate Model**

**Regression Output**

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**ANOVA**

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<th>F</th>
<th>Significance F</th>
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<tr>
<td>Regression</td>
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<td>0.02571741</td>
<td>0.02571741</td>
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<td>Total</td>
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**Coefficients**

<table>
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<th>Coefficient</th>
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<th>Lower 95%</th>
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<tr>
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**Multivariate Model**

**Summary Output**

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**ANOVA**

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<tr>
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**Coefficients**

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>Standard Error</th>
<th>t Stat</th>
<th>P-value</th>
<th>Lower 95%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-4.263065567</td>
<td>0.120324561</td>
<td>-35.42972048</td>
<td>2.26328E-84</td>
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<td>p at time t</td>
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<tr>
<td>p* at time t</td>
<td>0.280993705</td>
<td>0.051442984</td>
<td>5.462235746</td>
<td>1.50159E-07</td>
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</table>
Appendix E: Hypothesis Testing for Relative PPP in the Cross-Country Analysis

E.1 Testing for intercept = 0 and slope = 1 at a significance level of 5% via the P-VALUE Approach

\[ \% \Delta E = \beta_0 + \beta_1 (\Pi^* - \Pi) + u \]

\[ \% \Delta E_i = \hat{b}_0 + \hat{b}_1 (\Pi^*_i - \Pi_i) + u_i \]

******

\[ H_0: \beta_0 = 0 \]
\[ H_a: \beta_0 \neq 0 \]

\[ t^* = \frac{(b_0 - \beta_0)}{S_{b_0}} \]
\[ = \frac{(1.61 - 0)}{4.8463 \times 10^{14}} \]
\[ = 33221216516827.00 \]

\[ P = \text{TDIST}(|t^*|, n-2, 2) = \text{TDIST}(33221216516827.00, 72-2, 2) = 0 \]

\[ P < \alpha, \text{ reject } H_0 \]

The data rejects the hypothesis that the constant (intercept) is equal to 0 at a 5% significance level.

******

\[ H_0: \beta_1 = 1 \]
\[ H_a: \beta_1 \neq 1 \]

\[ t^* = \frac{(b_1 - \beta_1)}{S_{b_1}} \]
\[ = \frac{(1 - 1)}{1.8461 \times 10^{7}} \]
\[ = 0 \]

\[ P = \text{TDIST}(|t^*|, n-2, 2) = \text{TDIST}(0, 79-2, 2) = 1 \]

\[ P > \alpha, \text{ fail to reject } H_0 \]

The data accepts the hypothesis that the coefficient of the inflation differential between US and the other 78 nations is a unit (i.e., one) at a 5% significance level.
E.2 Testing for intercept = 0 and slope = 1 at a significance level of 5% via the CRITICAL VALUE Approach

\[ \%\Delta E = \beta_0 + \beta_1 (\Pi^* - \Pi) + u \]
\[ \%\Delta E_t = \hat{\beta}_0 + \hat{\beta}_1 (\Pi^*_t - \Pi_t) + u_t \]

********

\[ H_0: \beta_0 = 0 \]
\[ H_a: \beta_0 \neq 0 \]

\[ t^* = \frac{(b_0 - \beta_0)}{S_{b_0}} \]
\[ = \frac{(1.61 - 0)}{4.8463 \times 10^{14}} \]
\[ = 33221216516827.00 \]
\[ c = \text{TINV} (\alpha, n-2,) = \text{TINV} (0.05, 77) = 1.99 \]

|t*| > c, hence reject \( H_0 \)

The data rejects the hypothesis that the constant (intercept) is equal to 0 at a 5% significance level.

********

\[ H_0: \beta_1 = 1 \]
\[ H_a: \beta_1 \neq 1 \]

\[ t^* = \frac{(b_1 - \beta_1)}{S_{b_1}} \]
\[ = \frac{(1-1)}{1.8461 \times 10^7} \]
\[ = 0 \]
\[ c = \text{TINV} (\alpha, n-2,) = \text{TINV} (0.05, 77) = 1.99 \]

|t*| < c, hence fail to reject \( H_0 \)

The data accepts the hypothesis that the coefficient of the inflation differential between the US and the other 78 nations is a unit at a 5% significance level.
Appendix F: Regression Output for Relative PPP in Cross-Country Analysis

SUMMARY OUTPUT

<table>
<thead>
<tr>
<th>Regression Statistics</th>
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<tbody>
<tr>
<td>Multiple R</td>
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<td>R Square</td>
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<tr>
<td>Adjusted R Square</td>
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<tr>
<td>Standard Error</td>
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<td>Observations</td>
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<td>Regression</td>
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<tr>
<th>Coefficients</th>
<th>Standard Error</th>
<th>t Stat</th>
<th>P-value</th>
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<tr>
<td>Intercept</td>
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<td>3.3221E+13</td>
<td>0</td>
</tr>
<tr>
<td>Inflation Differential (regressor)</td>
<td>1.84605E-17</td>
<td>5.417E+16</td>
<td>0</td>
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