E C O N O M I C S   B U L L E T I N

Does PPP hold for Big Mac price or consumer price index? Evidence from panel cointegration

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Abstract

This paper examines the validity of purchasing power parity (PPP) using CPI and Big Mac prices. The benchmark model, i.e., the OLS method, which does not take nonstationarity into account, rejects the hypothesis of PPP regardless of prices used. We next use the panel cointegration method to consider the nonstationary nature of variables. Estimated results for CPI are mixed. The PPP is rejected when the nominal exchange rate is employed as the dependent variable but is not rejected when the price ratio is used as the dependent variable. By contrast, the PPP is overwhelmingly not rejected when the Big Mac price is used. Last, we remove the production bias and re-examine the same issue by using panel cointegration. The PPP is again decisively rejected when CPI price is used but not for Big Mac price. Accordingly, Big Mac price is more supportive to the validity of PPP than CPI price.

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1 Introduction

The doctrine of the purchasing power parity (PPP hereafter) is perhaps one of the oldest and most widely research area in international finance. The idea of PPP is a direct generalization of the law of one price for the same goods at different location in the presence of geographical arbitrage. It is well-known that the theoretical parity holds true under very strict conditions, such as almost no transaction costs, trade restrictions, taxation and the central bank interventions. Thus, whether the validity of PPP still holds true when these assumptions are not met is unknown.

Empirical studies of testing PPP get mixed results. In the early stage, researchers regress the log of the exchange on the relative prices by examining the slope coefficient of the unity, where the prices are typically proxied by the consumer price index (CPI) or wholesale price index (WPI). The unit coefficient implies the validity of the PPP. Employing this regression, Frankel (1978) reports the positive results of the PPP on hyperinflation countries in the 1920s. Other studies using the similar technique reject PPP. For example, Frenkel (1981) rejects PPP by using CPI and WPI as price measurements for industrialized countries during the 1970s. See also Isard (1977) and Adler and Lehman (1983). These early studies are soon challenged by the finding that nonstationarity, which is characterized in the exchange rate and the price indices, invalidates the conventional testing methods.[1] To remedy this approach, Engle and Granger's (1987) cointegration approach, suggesting that a linear combination of the exchange rate and the relative prices should be stationary, is applied. The PPP suggests that two countries' price levels as well as exchange rate should not drift apart but be cointegrated. Rejecting the null of no cointegration implies that the "real exchange rate" is stationary, and hence PPP is valid. Researches using this approach have increased significantly due to its simplicity and interesting application.[2] Simply testing whether the three variables are cointegrated or not, however, is in fact a less stringent testing method since it does not request the unit slope coefficient. A more advanced step is to adopt Johansen and Juselius's (1990) maximum likelihood method (MLE) to test the unit slope coefficient. Cheung and Lai (1993) and Pippenger (1993) apply the MLE to test the unity slope and reject the hypothesis.

Recent studies have used a broad panel of countries to pursue the same issue. A wide variety of country samples is expected to enhance the testing power of the PPP. The panel cointegration is adopted to take both panel of countries and nonstationarity

[1] Conventional testing statistics do not converge in distribution to the normal when the variables are nonstationary. See Phillips (1986).

[2] See Enders (1988), Mark (1990), Patel (1990), and Choudry et al. (1991) for example, use Engle and Granger's (1987) method.

of variables into account.[3] Results, however, are not smoothing. O'Connell (1998), Wu and Chen (1999) and Pedroni (2004) reject the mean reversion of the real exchange rate (i.e., the existence of the PPP), but Frankel and Rose (1996), MacDonald (1996), Oh (1996), Papell (1997), Coakley and Fuertes (1997) and Nagayasu (1998) accept it. Kuo and Mikkola (2001), however, argue that the often used null hypothesis of no PPP should be reversed, that is, the null should be the validity of PPP. Their results cannot reject this "right null".

While there are researches using CPI, WPI or general price level (Oh, 1996), researchers argue that the uses of CPI and WPI are wrong in two aspects. First, when consumption bundles are not identical, even though the law of one price holds for each commodity, price indices based on local consumption patterns may behave differently, resulting in biased outcomes of PPP tests (Betton et al., 1995). Second, both CPIs or WPIs are contaminated by non-tradable goods and the former is worse of the two (Kim, 1990). Thus, it may not be surprising that the testing of PPP using the CPI or WPI may yield mixed results.[4]

Recent studies shift their attention to using another price index as a study target. Cumby (1996), as far as we know, is the first using *the Economist's* Big Mac price to study PPP, where the Big Mac is McDonald's Big Mac sandwich. The attractive feature of using Big Mac to study PPP is its uniform composition. With few exceptions, the components ingredients of Big Mac are the same everywhere around the globe. The use of the Big Mac standard, hence, fulfills at least the requirements of the same goods in testing the law of one price. The estimation bias may be thus considerably reduced. It is, however, undeniable that though Big Mac is a more uniform product than CPI, it still fails to meet other strict premise of the law of one price, such as barriers to trade, productivity bias arising from non-tradable components, wage rate and tax (Pakko and Pollard, 1996). Ong (1997) further adjusts the productivity bias proxy of the tradable goods when using Big Mac. He finds that the over/under value of the currency is further reduced. Click (1996) also finds support for PPP using Big Mac prices.

The aim of this paper is to compare the validity of PPP using the Big Mac index (BMI) and the CPI. Our paper differs from the past ones in two aspects. First, we apply panel cointegration to both BMI and CPI across 16 countries. Previous studies

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[3] The panel cointegration technique is widely used in various areas. For example, in addition to the testing of the purchasing power parity, it is also applied to real exchange rate and productivity differentials in OECD countries (Canzoneri, Cumby and Diba, 1999; Chinn, 1996), as well as human capital accumulation and the economic growth (Pedroni, 1997).

[4] There are more issues discussed in the literature, such as the results are sensitive to the sample period (Chortareas and Driver, 2001) and numeraire currency (Papell and Theodoridis, 2001). See Rogoff (1996), Froot and Rogoff (1995), and Taylor (2002) for a survey.

employ panel cointegration to CPI, but not BMI, to test PPP. While this application may be non-crucial at first glance, it has significant implications. Because Big Mac has a clear advantage of uniformity over CPI, the results would shed light on the importance of this requirement for inferring the validity of PPP. While BMI also contains nontrivial non-tradable goods (Pakko and Pollard, 1996), these parts are far less than those in CPI. If BMI is indeed a preferable choice, consideration of the single goods may be important for investigating PPP.

Next, the adjustment of the productivity bias is taken into account. While it is fully recognized that the productivity of the non-traded goods affect systematically the deviation from PPP, few, except for Ong (1997), have taken this into account. Balassa (1964) and Samuelson (1964) argue that non-tradables are more productive in high-income than in low-income countries, thus creating a higher price in high-income countries. Consequently, the currencies of these countries will appear overvalued relative to the currencies of low-income countries. Our study has adjusted for this bias.

Four sections are included in this paper. The next section discusses the methodology of panel unit root and panel cointegration used in this paper. Section 3 is the empirical results. The last section presents the conclusion.

2 Panel Unit Root and Panel Cointegration

2.1 Panel Unit Root

Investigation of unit root in panel data has recently attracted a lot of attention. Quah (1994), Levin, Lin, and Chu (2002) and Im, Pesaran, and Shin (2003) develop the testing statistics with the null hypothesis of unit root. Hadri (2000) argue that the null should be reversed to be stationary hypothesis to have a stronger power test. We follow this suggestion by using the Lagrange multiplier (LM) test, which assumes that the processes are stationary under the null and nonstationary under the alternative. Moreover, Hadri (2000) showed that the asymptotic distributions of LM statistics are normally distributed under this null.

2.2 Panel Cointegration

The cointegration test is next performed when the two series are nonstationary. The panel cointegration is proceeded as follows.

$$S_{it} = \alpha_i + \beta_i p_{it} + \varepsilon_{it} \qquad (1)$$

where S_{it} is the natural log of nominal exchange rate and $p_{it} = P_{it} - P_t^*$ and P_{it} and P_t^* are the natural log of country i and the US price level respectively.

In a bivariate context, Pedroni (2004) develops asymptotic and finite-sample properties of testing statistics to examine the null hypothesis of non-cointegration in the panel. When testing the above model, both α and β are allowed to vary across countries since there is no reason to believe that all parameters are the same across countries.

Two types of tests are suggested by Pedroni to allow heterogeneous individual effects. The first type is the pooled panel cointegration test, which includes four statistics. They are panel ν-statistic, panel ρ-statistic, panel ADF-statistic and panel PP-statistic. The panel ρ-statistic which effectively pools the autoregressive coefficient ρ from the regression of $\varepsilon_{it} = \rho\varepsilon_{it-1} + \mu_{it}$ while correcting the number specific serial correlation properties. The third one resembles the conventional unit root test of augmented Dickey-Fuller (ADF) and the fourth statistic is similar to those in Phillips and Perron (1988) by allowing heteroscedasticity in the residual. The above pooled panel cointegration statistics do allow the intercept and slope coefficients to vary across countries, however, the autoregressive coefficient of errors ρ_i are assumed to be the same.

The pooled panel cointegration statistics are calculated as

$$\text{Panel } \nu\text{-statistic} = \left(\sum_{i=1}^{N}\sum_{t=1}^{T} L_{11i}^{-2} e_{it-1}^{2}\right)^{-1} \tag{2}$$

$$\text{Panel } \rho\text{-statistic} = \left(\sum_{i=1}^{N}\sum_{t=1}^{T} L_{11i}^{-2} e_{it-1}^{2}\right)^{-1} \sum_{i=1}^{N}\sum_{t=1}^{T} L_{11i}^{-2} (e_{it-1}\Delta e_{it} - \lambda_i) \tag{3}$$

$$\text{Panel PP-statistic} = \left(\sigma^{2}\sum_{i=1}^{N}\sum_{t=1}^{T} L_{11i}^{-2} e_{it-1}^{2}\right)^{-1} \sum_{i=1}^{N}\sum_{t=1}^{T} L_{11i}^{-2} (e_{it-1}\Delta e_{it} - \lambda_i) \tag{4}$$

$$\text{Panel ADF-statistic} = \left(\sigma^{*2}\sum_{i=1}^{N}\sum_{t=1}^{T} L_{11i}^{-2} e_{it-1}^{*2}\right)^{-1} \sum_{i=1}^{N}\sum_{t=1}^{T} (L_{11i}^{-2}\Delta e_{it-1}^{*} - \Delta e_{it}^{*}) \tag{5}$$

where e_{it} is the estimated residual from (1) and L_{11i}^{2} is the long run variance of Δe_{it}. Similarly, λ_i is the familiar nonparametric serial correlation correction term from the Phillips-Perron estimator. Thus, to obtain estimates for L_{11i}^{2} and λ_i one can simply estimate the residual autoregression $\varepsilon_{it} = \rho\varepsilon_{it-1} + \mu_{it}$ and then use the nonparametric kernel estimator such as the Newey-West estimator to obtain the corresponding long run sample variances in terms of Δe_{it} and μ_{it}, respectively. Further, σ^{*2} is the pooled long run variance estimator given as $\sigma^{*2} = \sum_{i=1}^{N} L_{11i}^{-2}\sigma_i^{2}$.

The second test is the group mean panel cointegration test, which is in the same spirit as the panel unit root of Im-Pesaran-Shin, where the group unit root test is conducted by averaging the statistics obtained from individual unit root test. The group mean panel cointegration not only assumes variation in intercept and slope across countries, but the model also allows for the possibility of heterogeneous coefficients of the autoregressive parameters ρ_i change. There are three group mean panel tests, including group ρ, group PP and group ADF tests.

The group mean panel cointegration statistics are calculated as

$$\text{Group}\,\rho\text{-statistic} = \sum_{i=1}^{N}\left(\sum_{t=1}^{T} e_{it-1}^{2}\right)^{-1}\sum_{t=1}^{T}\left(e_{it-1}\Delta e_{it} - \lambda_i\right) \tag{6}$$

$$\text{Group}\,\text{PP-statistic} = \sum_{i=1}^{N}\left(\sum_{t=1}^{T} L_{11}^{-2} e_{it-1}^{2}\right)^{-1/2}\sum_{t=1}^{T}\left(e_{it-1}\Delta e_{it} - \lambda_i\right) \tag{7}$$

$$\text{Group}\,\text{ADF-statistic} = \sum_{i=1}^{N}\left(\sum_{t=1}^{T} \hat{s}_i^{*2} \hat{e}_{it-1}^{*2}\right)^{-1/2}\sum_{t=1}^{T}\left(\hat{e}_{it-1}\Delta \hat{e}_{it}^{*}\right) \tag{8}$$

where $\hat{s}_i^{*2} = \frac{1}{T}\sum_{t=1}^{T}\hat{\mu}_{it}^{*2}$.

For the panel ν-statistics, large positive values indicate rejections, whereas for the remaining testing statistics, large negative values indicate rejection of the null of no cointegration. The critical values are also tabulated by Pedroni (1999).

3 Empirical Results

Annual data of 16 countries, including Argentina, Australia, Brazil, Britain, Canada, China, Denmark, France, Germany, Hong Kong, Hungary, Italy, Japan, Korea, Spain, and Sweden, are used here. The sample period covers from 1992 to 1999. The nominal exchange rate and consumer price index series are collected from the *International Financial Statistics (IFS)* published by the International Monetary Fund. The Big Mac price series is obtained from various issues of *The Economist*. The series of real GDP per capita is collected from World Bank's World Development Indicator CD-ROM.[5]

Using data from all countries, Figure 1 plots the logarithm of the Big Mac price ratio (Big Mac price in i country / Big Mac price of U.S) to the logarithm of the nominal exchange rate; and the CPI ratio (CPI price of i country / CPI price of U.S.) to the nominal exchange rate, respectively. It is found that the plot is almost 45 degree for the top panel but is less obvious for the bottom panel. Thus, according to these two plots, Big Mac seems to be more supportive than CPI for PPP.

3.1 Absolute and Relative PPP

In this section, we firstly use the OLS technique to verify the PPP hypothesis. We consider two different versions of PPP hypothesis, i.e. absolute PPP and relative PPP. The absolute PPP is the relationship between nominal exchange rate and the corresponding relative price level in terms of level form, which is

$$s_t = \alpha + \beta p_t + \varepsilon_t \tag{9}$$

The relative PPP is expressed as the first difference form, i.e.

$$\Delta s_t = \alpha + \beta \Delta p_t + \varepsilon_t \tag{10}$$

where Δ is the first difference operator.

The null hypothesis of both absolute and relative PPPs is that α and β should be zero and unity, respectively. OLS estimation is applied to equations (9) and (10) as the benchmark. Table 1 displays the OLS results of using Big Mac and CPI prices, respectively. When the Big Mac price is employed, the coefficients (α, β) for

[5] The real GDP per capita is available until 1999, which determines our sample period.

the absolute and relative PPP are (0.388, 0.745) and ($0.094, -0.068$), respectively. With the conventional *F*-statistics, the joint test of $\alpha = 0$ and $\beta = 1$ is rejected at the 5% level. When CPI prices are taken, the estimated coefficients are (2.486, 1.479) and (0.027, 1.004) for the absolute and relative PPP models, respectively. While the estimated coefficients of using CPI prices are closer to the requirement of the null, the *F*-tests still reject the null hypothesis.

The rejection of either PPP may be due to the nonstationary nature inherently characterized in the data. The next subsection remedies this problem by using the panel cointegration approach.

3.2 Panel Cointegration

Before conducting the panel cointegration test, we need to verify whether the series in our study contains a unit root.

Table 2 reports the results of Hadri's panel unit root tests for nominal exchange rate (s_{it}), Big Mac price ratio (bp_{it}), CPI ratio (cpi_{it}), and relative real GDP per capita (g_{it}). Results overwhelmingly reject the null hypothesis of no unit root for all series, except for using Z_τ statistic which considers heteroskedastic disturbances. Thus, they are nonstationary variables.

Once the variables contain unit roots, the next step is to implement the panel cointegration tests. Two tests are found in the literature for testing the cointegration, depending on which variable is the dependent variable. Putting the nominal exchange rate on the left, which is the first approach, is typically found in the literature (Nagayasu, 1998; Pedroni, 2001), that is,

$$\text{Model A}: s_{\text{it}} = \beta_{0i} + \beta_{1i} p_{it} + \varepsilon_{it} \qquad (11)$$

where p_{it} denotes the Big Mac price ratio or CPI ratio. Thus, price ratio is expected to offset the nonstationary part of the nominal exchange rate when the two series are cointegrated.

Alternatively, Isard (1977) and Click (1996) put the price ratio, p_{it}, on the left, which is

$$\text{Model B}: p_{\text{it}} = \beta_{0i} + \beta_{1i} s_{it} + \varepsilon_{it} \qquad (12)$$

Then, the nominal exchange rate is expected to offset the nonstationary part of price ratio.

The empirical results of panel cointegration for Models A and B, are summarized in Tables 3. When CPI is employed as the price index, mixed results are found. The null of no cointegration is rejected when Model A is tested by using panel μ-statistic, panel PP-statistic, panel ADF-statistic, group PP-statistic and group ADF-statistics. However, the null of no cointegration cannot be rejected for Model

B of all testing statistics. When Big Mac is employed as the price index, the null hypothesis of no cointegration is rejected for either model. Hence, our panel cointegration statistics suggest that PPP is more likely to hold true for Big Mac price and less likely for CPI price.

3.3 Effect of Productivity Bias

Balassa (1964) and Samuelson (1964) argue that when all country's price levels are translated into dollars, rich countries tend to have higher price levels than poor countries. They conjecture that rich countries are relatively more productive in the tradable goods. In this section, we consider two methods for adjusting this productivity bias. First, we add real GDP per capita to cointegration regression as follows.

$$\text{Model C}: p_{\text{it}} = \beta_{0i} + \beta_{1i}s_{it} + \beta_{2i}g_{it} + \varepsilon_{it} \qquad (13)$$

where g_{it} is the natural log of real GDP per capita for country i over the US's.

The second method is a two-step estimation (Model D). Firstly, regress p_{it} on g_{it} to remove the productivity bias as equation (14).

$$p_{it} = \gamma_{0i} + \gamma_{1i}g_{it} + u_{it} \qquad (14)$$

The residuals $\hat{u}_{it}$ can be regarded as the prices level after adjusting the productivity bias. Next, we perform Pedroni's panel cointegration test for s_{it} and $\hat{u}_{it}$.

$$s_{it} = \beta_{0i} + \beta_{1i}\hat{u}_{it} + \varepsilon_{it} \qquad (15)$$

The PPP hypothesis holds if the null hypothesis of non-cointegration is rejected.

Table 4 presents the estimated results after adjusting the productivity bias using CPI and Big Mac price indices, respectively. When CPI is used, panel cointegration test indicates that the null hypothesis of no cointegration cannot be rejected for either model. In contrast, when Big Mac price is used, the null can be rejected at the 1% significance level when using tests of panel PP-statistic, group PP-statistic, and group ADF-statistic in Model C and tests of panel ADF-statistic, panel ADF-statistic, group PP-statistic, and group ADF-statistic in Model D. While not all testing statistics reject the null, more than two-thirds have rejected the null of no cointegration. Therefore, after removing the productivity bias, Big Mac price supports the PPP to some extent but CPI price rejects the PPP decisively.

4 Conclusion

This paper examines the validity of purchasing power parity using CPI and Big Mac prices. The attractive feature of using the Big Mac prices to study PPP is its uniform composition. With few exceptions, the component ingredients of Big Mac are the same everywhere around the globe. The use of the Big Mac standard, hence, fulfills at least the requirements of the same goods in testing the law of one price.

The benchmark model, i.e., the OLS method, which does not take nonstationarity into account, rejects the hypothesis of PPP regardless of prices used. We next use the panel cointegration method to consider the nonstationary nature of variables. Estimated results for CPI are mixed. The PPP is rejected when the nominal exchange rate is employed as the dependent variable, but is not rejected when the price ratio is used as the dependent variable. By contrast, the PPP is overwhelmingly not rejected when the Big Mac price is used. Last, we remove the production bias and re-examine the same issue using panel cointegration. The PPP is again decisively rejected when CPI price is used but not for Big Mac price. Accordingly, the use of Big Mac price gains more support for the validity of PPP than CPI price.

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Table 1：OLS Regression for Absolute PPP and Relative PPP

	CPI		Big Mac Price	
	Absolute PPP	Relative PPP	Absolute PPP	Relative PPP
constant	2.486	0.027	0.388	0.094
	(11.449)***	(2.975)***	(1.740)***	(2.386)**
$\ln(P_{i,t} / P_{us,t})$	1.479		0.745	
	(4.515)***		(12.411)***	
$\Delta \ln(P_{i,t} / P_{us,t})$		1.004		-0.068
		(44.321)***		(-1.569)
Joint test:	F(2,126)	F(2,110)	F(2,126)	F(2,110)
$\alpha = 0$ and $\beta = 1$	$= 65.541$***	$= 4.680$***	$= 10.729$***	$= 230.559$***

Note: The symbols *, **, and *** indicate significant at the 10%, 5%, and 1% level, respectively.

Table 2：Hadri Panel Unit Root Test

	Homoskedastic disturbances		Heteroskedastic disturbances	
	Z_μ	Z_τ	Z_μ	Z_τ
s_{it}	8.938***	6.612***	5.713***	2.896***
bp_{it}	10.234***	2.885***	6.463***	0.879***
cpi_{it}	8.737***	7.206***	10.900***	5.244***
g_{it}	11.281***	5.307***	6.400***	3.853***

Note: The null hypothesis is the series are stationary. The symbols *, **, and *** indicate significant at the 10%, 5%, and 1% level, respectively.

Table 3：Pedroni Panel Cointegration Test for Model A and B

	CPI		Big Mac	
	Model A	Model B	Model A	Model B
Panel ν - statistic	2.841***	−1.311	1.829***	1.112
Panel ρ - statistic	−0.562	1.498	−1.021	0.029
Panel PP-statistic	−2.142***	0.736	−4.021***	−2.575***
Panel ADF-statistic	−2.510***	1.156	−3.540***	1.465
Group ρ - statistic	1.342	3.033	0.802	0.678
Group PP-statistic	−2.144***	1.758	−5.474***	−5.632***
Group ADF-statistic	−4.937***	1.386	−8.258***	−5.180***

Note: The null hypothesis is the series are stationary. The symbols *, **, and *** indicate significant at the 10%, 5%, and 1% level, respectively.

Table 4：Pedroni Panel Cointegration Test for Model C and D

	CPI		Big Mac	
	Model A	Model B	Model A	Model B
Panel ν - statistic	−1.284	1.116	0.152	0.978
Panel ρ - statistic	2.077	−0.005	0.934	−0.219
Panel PP-statistic	0.599	−1.582	−2.877***	−2.968***
Panel ADF-statistic	0.646	−1.029	−0.734***	−2.963***
Group ρ - statistic	3.462	1.755	1.967	1.283
Group PP-statistic	0.501	−1.251	−5.795***	−4.645***
Group ADF-statistic	−0.905	−1.440	−4.113***	−5.530***

Note: The null hypothesis is the series are stationary. The symbols *, **, and *** indicate significant at the 10%, 5%, and 1% level, respectively.

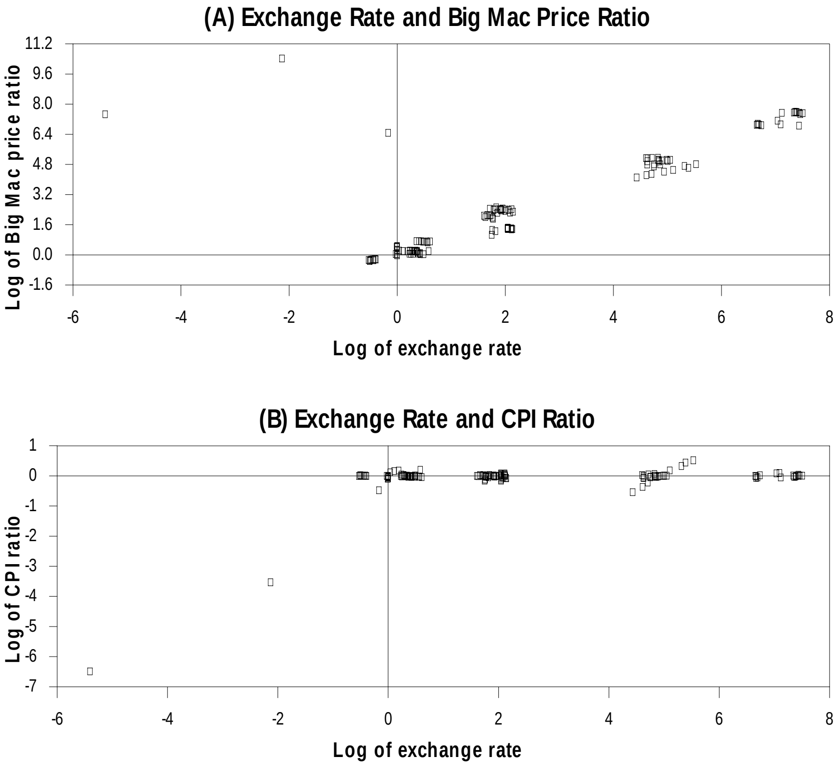

Figure 1: Log Exchange Rates and Relative Prices