Testing Purchasing Power Parity in the Long-Run

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This paper studies the validity of the long-run purchasing parity hypothesis. The five currencies of interest in this study are the U.S. dollar, the U.K. pound sterling, the German mark, the French franc, and the Japanese yen. I attempt two approaches to test the long-run PPP hypothesis. First, I test for unit roots of the real exchange rates themselves. Second, I examine the cointegration relationship between the foreign dollar price level and the Canadian price level. Results show that the long-run PPP hypothesis cannot be confirmed.

INTRODUCTION

The purchasing power parity (PPP) hypothesis is one of the most controversial topics in the field of international finance. Many theoretical and empirical models have been built on the assumption that it holds. Although, this topic has been researched extensively, no unique answer exists as to whether it holds in the real life to date. It is a well-known fact that substantial departures from the PPP are possible in the short-run. The empirical results on the long-run validity of the PPP have yielded contradictory results depending upon the particular currencies under consideration, the price indices used to measure price levels or inflation, the particular time period under investigation, and the method of the analysis used. For example, a number of researchers such as Enders (1995), McDonald (1992), Zhou (1997), Chen (1995) have demonstrated that the long-run PPP holds. Other researchers such as Cochran and DeFina (1995), Fung and Lo (1992), In and Sugema (1995) have shown that departures from the PPP are permanent. However, researchers such as Henricsson and Lundback (1995), Whitt (1989), and Glen (1992) have obtained mixed results that were neither in favour nor against the PPP hypothesis.

In this study I use the time series of exchange rates and consumer price indices from January 1982 to May 1997. The data set is downloaded from the following website: http://www.economagic.com/ Unfortunately, the data is discontinued and an analysis on an extended dataset is not possible. The five currencies of interest in this study are the U.S. dollar, the U.K. pound sterling, the German mark, the French franc, and the Japanese yen. Canada is used as the base country.

This study employs the univariate unit root approach to test for the stationarity of real exchange rates of five industrialized countries. I also apply the Sims test, introduced by Christopher A. Sims in 1988, to real exchange rates (Whitt, 1989). The Sims test is less sensitive to the spurious acceptance of the unit root. An alternative way to check the validity of the PPP hypothesis is to conduct the cointegration analysis of the foreign and local price levels. The Engle-Granger cointegration test shows that price levels in the U.K. and Canada are cointegrated. I estimate the error-correction model for the U.K. and Canadian price levels.

The rest of the paper is organized as follows. In the next section I give an overview of the PPP concept. The third section presents a review of empirical problems that are associated with testing the

PPP. The fourth section outlines the methodology used in this paper and presents empirical results. The fifth section contains the conclusion.

THE CONCEPT OF PURCHASING POWER PARITY

The theory of the PPP is based on the law of one price, which says that prices of identical goods should be equalized across markets. Under the conditions that the same goods are included in the price indices and that price indices are constructed identically, the law of one price generalizes to the absolute version of the PPP, which is given in the following equation:

$$P^d = P^f \times E, \tag{1}$$

where E is the nominal exchange rate in period t; P^d is the domestic price level; and P^f is the foreign price level.

An alternative way of expressing the absolute PPP is through the real exchange rate. The real exchange rate is viewed as a measure of a country's competitiveness versus another country (in our case, versus Canada) and may be expressed as:

$$R_t = E \times \left(P^f / P^d\right) \tag{2}$$

If foreign prices are greater than domestic prices and this is not offset by a depreciation of the foreign currency, then a real appreciation of the foreign currency will follow and, therefore, the foreign country will become uncompetitive (Cooper, 1994). If the PPP holds so that $E = \left(P^d / P^f\right)$, then the value of R_t should be unity. Alternatively, taking logs of both sides of the equation (2) one gets the following expression:

$$\log R_t = \log E + \log P^f - \log P^d \tag{3}$$

And because R_t should be unity in the equation (2), log R_t should be zero.

From the equation (3), the long-run PPP implies that if the nominal exchange rate, domestic and foreign price indices are I (1), then they are cointegrated with the cointegration vector (1, -1, 1). Thus, the long-run PPP can be validated if a cointegration vector, (1, -1, 1), can be found for the nominal exchange rate and the two price indices. If the long-run PPP holds, then deviations from the PPP in the short-run are assumed to be transitory. Since the real exchange rate measures the deviation from the PPP, testing the PPP in the long-run is equivalent to testing the real exchange rate for stationarity.

A weaker version of the PPP, the relative PPP, states that the equation $E = \left(P^d / P^f\right)$ is expected to hold up to a constant or that the nominal exchange rate moves to compensate for the differences in the inflation rate:

$$\Delta E = \Delta P^d - \Delta P^f \tag{4}$$

It has been argued in the literature that deviations from the PPP may be caused by a multitude of different factors, including transportation costs, tariffs and other restrictions on trade, tax differences across countries, the existence of non-traded goods and services, relative price changes, differential speeds of adjustment in the currency exchange and goods markets, as well as problems associated with the construction of price indices.

A REVIEW OF EMPIRICAL PROBLEMS ASSOCIATED WITH TESTING PPP

The empirical studies of the PPP hypothesis often include a few common problems. I discuss some of these problems next.

Choice of the Price Index

The choice is often made between the consumer price index (CPI), the wholesale price index (WPI), and/or the GDP deflator. The CPI represents the consumer basket of goods, whereas the WPI represents a basket of goods traded more often across nations. It is argued that the WPI is a more suitable choice for the price index, because the inclusion of non-traded goods in price indices is often considered as an explanation for deviations from the PPP. As Macdonald (1995) notes: "since both of these measures incorporate prices of non-traded goods, it is unlikely that their use in an empirical test would produce the symmetry and proportionality…, although these conditions are most likely to hold for tests construed using wholesale prices, a series that contains a relatively large traded goods element." Although, In and Sugema (1995) argue that the definition of traded and non-traded goods vary widely across the countries. The GDP deflator is viewed to be a superior measure of a country's price level to either the CPI or the WPI, because it assigns an appropriate weight to each good, no matter what classification is chosen.

Non-Stationarity of the Time-Series

The univariate tests frequently used to check for the stationarity of the series include: Dickey-Fuller tests, augmented Dickey-Fuller tests, and Phillips-Perron tests. The Phillips-Perron tests allow disturbances to be serially correlated as well as heteroscedastic. Therefore, Phillips-Perron tests are deemed superior to Dickey-Fuller tests. The problem with the unit root tests is that they are biased toward the acceptance of the unit root hypothesis unless there is strong evidence against it. The result also depends on whether the constant and/or trend are included. If the model is incorrectly specified, the power of the test decreases. Therefore, in practice one should estimate models with and without constant and/or trend.

Sims, in 1988, proposed another test to test for a random walk. First, he suggests estimating the following simple regression:

$$Y_t = \rho Y_{t-1} + \varepsilon_t \tag{5}$$

The value of the autoregressive ρ is crucial in evaluating the long-run behaviour of the real exchange rate. This test is based on the "Bayesian posterior odds ratio" (Whitt, 1989). To apply the Sims test, one needs to estimate the regression model (5), where the null hypothesis is that $\rho=1$ and the alternative hypothesis is that $\rho<1$. In order to perform this test one needs to specify a prior distribution of ρ. The Sims approach puts a prior on the ρ, which spreads the probability γ of observing ρ evenly between 0 and 1. Sims suggests giving the unit root a probability of (1-γ), where γ lies between 0 and 1. Sims thought that unit roots are uncommon in economic data, and, therefore, suggested to use $\gamma=0.8$. This implies that the unit root probability equals to 0.2. The test criterion is: The null hypothesis of a unit root is accepted if $Z>0$, where $Z=2*\log((1-\gamma)/\gamma)-\log(\sigma p^2)+2*\log(1-2^{-1/s})-2*\log\{\varphi(\tau)\}-\log(2\pi)-\tau^2$, and ρ is the estimate of ρ obtained from the regression of a real exchange rate on its own lagged value; σp is the standard error of ρ; τ is the conventional t-statistic for testing that $\rho=1$ and equals to $(1-\rho)/\sigma p$; $\varphi(\tau)$ is the cumulative distribution function for the standard normal distribution evaluated at τ; and s is the number of periods per year ($s=12$ for monthly data). The alternative hypothesis is accepted if Z is less than 0.

If nominal exchange rates and price series are I (1), then there exist an alternative way to check the theory of PPP. This method is called the cointegration technique. The most widely used method to check for cointegration is the Engle-Granger method. The advantage of the Engle-Granger approach is that coefficient estimates of the cointegrating regression are super consistent in that they approach their asymptotic values at the rate equal to T rather than the conventional $T^{1/2}$. If there is a possibility for more than one cointegrating vector, the Johansen procedure is deemed to be more appropriate. The Johansen procedure allows one to test for the presence of multiple cointegrating vectors. However, Cheung and Lai (1993) indicate that asymptotic critical values of Johansen's likelihood ratio tests can be biased towards finding cointegration in finite samples. Huang and Yang (1996) use the Monte-Carlo simulation and find that the Johansen procedure has a bias towards supporting the existence of cointegration, especially in the case when the assumption of normally and identically distributed error terms is violated. They, as well as Cheung and Lai (1993), claim that the Engle-Granger two-step method has greater power than the Johansen maximum likelihood approach for testing the existence of cointegration if even one of the variables entering the system deviates from normality.

Problems of Simultaneity

It is possible in the context of testing the PPP that both exchange rates and prices may be endogenous (Mcdonald, 1995). For example, some academicians argue that the PPP can be falsely rejected when it is true, because the estimates of price coefficients will be biased towards zero. The problem can be removed using the instrumental variable method of estimation. Sharma, Mathur, and Wong (1991) perform Granger causality tests and conclude that their results do not strictly support the view that prices cause exchange rates. It should be said that the problem of simultaneity bias does not arise in the cointegration framework of Engle and Granger. If prices and exchange rates are integrated of the same order and cointegrated, the tendency of the low-frequency components to dominate the high-frequency components in the cointegration regression will allow the researcher to abandon an explicit consideration of the "direction of causality." (Anonymous, 1992).

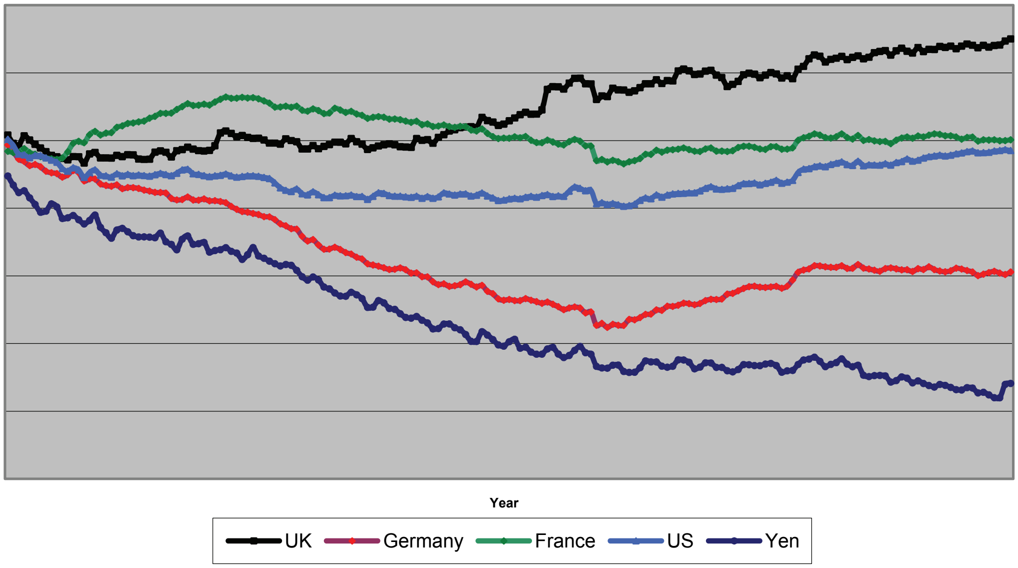
Cross-Sectional and Panel Data Estimation of PPP

Some researchers argue that in situations where the time series variation in the data is insufficient in order to get reasonably good power for the unit root testing, combining data into cross-sectional data or pooling can result in a substantial improvement. Panel unit root tests involve estimation of the following regression: $\Delta R_{jt} = \mu_j + \alpha R_{jt-1} + \sum_{i=1}^{k} c_{ji} \Delta R_{jt-1} + \varepsilon_{jt}$, where the subscript j=1… n indexes the countries. The panel test is designed to evaluate the null hypothesis that each individual series are I (1) versus an alternative hypothesis that all series in a panel are stationary. This method was popularized by Levin-Lin and applied by MacDonald (1995). This testing method produces a single t-ratio for the panel and this statistic is demonstrated to have a standard normal distribution. The results of MacDonald's (1995) research indicate that the null of the unit root for his sample of real exchange rates is rejected, whereas that of the stationarity - accepted.

THE EMPIRICAL RESULTS

The long-run PPP is said to hold if constructed series of real exchange rates are stationary. A critical first step to determine whether real exchange rates are, indeed, stationary is to visually inspect the data. The trajectories of all 5 real exchange rate series are illustrated in FIGURE 1 below.

FIGURE 1
THE TRAJECTORIES OF REAL EXCHANGE RATES



Recall, that the PPP hypothesis holds if the logarithm of the real exchange rate equals to zero. As can be seen from FIGURE 1, real exchange rates are not exactly equal to zero, but rather exhibit the random walk behaviour. Autocorrelation functions of real exchange rates in the level form, which are not reported here to save space, show almost no tendency to decrease, whereas those in the differenced form show a pattern similar to that observed for stationary time-series.

I also perform a graphical analysis of the absolute PPP over time for selected countries. I compare spot exchange rates (relative to the Canadian dollar) with relative prices ($P^d/P^{C\$}$). An overvalued currency is one for which the ratio of price indices exceeds the exchange rate. I demonstrate that departures from the PPP are common. For example, the U.S. dollar, and the U.K. pound sterling have been consistently overvalued, whereas the Japanese yen and the French franc have been consistently undervalued against the Canadian dollar. Moreover, it is not obvious that there is a tendency for deviations to disappear over time. For the German mark, however, the spot exchange rate tracks relative prices reasonably well.

TABLE 1 gives the summary statistics on considered real exchange rates. Using Canada as the base country, series are calculated for five other industrialized nations: the U.K., the U.S., France, Germany, and Japan. The span of the time covered belongs to the period of flexible exchange rates, and the data have been normalized to make the value of real exchange rates equal to zero in January 1982. Because the data is expressed in logarithms, the mean represents the average discrepancy in percent over the entire period between the real exchange rate and its value in January 1982. For example, the mean for the United States is –5.9%, implying that the Canadian dollar was, on average, 5.9% less valuable relative to the U.S. dollar than it had been in January 1982.

The second column of the table gives the standard deviation, which is a measure of the dispersion around the mean. This indicator shows that real exchange rates have exhibited some variation. For example, a standard deviation of 8.98 percent for the Japanese real exchange rate implies that roughly one-third of the time this rate is more than 8.98 percent away from its average value.

The last two columns of TABLE 1 report the maximum and minimum values reached by each exchange rate during the period covered. In all five cases the switch from high to low was at least 50 percent, thus reinforcing the conclusion that exchange rates fluctuate considerably. In contrast, if the PPP hypothesis held exactly each month, real exchange rates would have been constant.

TABLE 1
SUMMARY STATISTICS FOR REAL EXCHANGE RATES

Country	Mean Percentage Variation* (Jan-82 = 100)	Standard Deviation (percent)	Maximum	Minimum
United States	-5.9	2.4	0.18	-9.7
United Kingdom	4.9	5.9	15	-3.3
Japan	-26.2	8.98	-5.2	-38
France	1.1	2.6	6.4	-3.4
Germany	-17.2	6.9	-0.65	-27.6

I use three different models to test real exchange rates for stationarity. The first is a pure random walk model, the second includes an intercept or drift term, and the third includes both a drift and a linear time trend. The problem is that in order to estimate these models, one should choose the appropriate lag length. Including too many lags can reduce the power of the test to reject the null hypothesis of a unit root since additional parameters are added to the equation, which constitutes a loss of degrees of freedom. However, including too few lags will lead to the imprecise estimation of γ and its standard error. I use the Box-Jenkins methodology to select the appropriate lag length. I use the pure random walk model with the initial lag length set at 12. It is important to allow for the lag length no shorter than 12 month with monthly data. If the t-statistic on lag 12 is insignificant at 5% critical level, I re-estimate the regression using a length of lag of 12-1. Such a procedure is repeated until I find a lag that is significantly different from zero. It is often claimed by econometricians that this procedure in the autoregressive case will yield the true lag length. Also Dickey-Fuller F-tests are performed in order to determine the appropriate lag length. Phillips-Perron test statistics are also obtained and compared with their critical values. Results of univariate tests[1] (Dickey-Fuller, augmented Dickey-Fuller tests, and Phillips-Perron tests) are predominantly favouring the unit root hypothesis of real exchange rates for selected countries.

For robustness purposes, I perform the Sims test. To do this, the log of the real exchange rate is regressed on its own lagged value to get estimates of ρ and $\sigma_{\rho.}$ The resulting estimates of the autoregressive coefficient ρ are substantially close to 1. Then, τ-statistics are computed according to the formula: $\tau = (1-\rho)/\sigma p$. Because calculated τ values for all countries are greater than the critical value of –2.89, I cannot reject the unit root hypothesis on the basis of the conventional t-test.

Another statistic for testing the Sims method includes the Z-statistic. The Sims test accepts the null hypothesis of a unit root if the calculated Z-statistic is positive. The middle column of the TABLE 2 reports Z values. These values are calculated using the prior probability for a unit root of $(1-\gamma)=0.2$. In all five instances, the calculated Z values are negative, favouring the alternative hypothesis that considered real exchange rates are stationary.

Whitt (1989) notes that a measure of the strength of rejection of the null hypothesis can also be calculated. Having information with respect to the estimates of ρ and $\sigma_{\rho,}$ I can "calculate the smallest probability on the null hypothesis, $(1-\gamma^*)$, that would be necessary in order to force the Sims criterion to favour the random-walk hypothesis"(Whitt, 1989). So, whether the rejection of the null hypothesis is strong or weak can be deduced from the value of the $(1-\gamma^*)$: the greater the value of the $(1-\gamma^*)$, the stronger the rejection of the null of a unit root. As demonstrated in the third column of the table 2, the null is rejected fairly strongly.

TABLE 2
SIMS TEST FOR A UNIT ROOT OF THE REAL EXCHANGE RATE

Country	Dickey-Fuller	Sims test	
	τ	Z	$(1-\gamma^*)$
US	0.35956	-1.41184	0.328105
UK	-1.26156	-2.375084	0.451001
France	1.00944	-2.282471	0.441173
Germany	-1.65662	-2.477548	0.461479
Japan	-2.40704	-4.2248	0.593707
The null hypothesis for both tests is that $\rho=1$. The critical value for the τ is –2.89, whereas for the Sims test the critical region is $Z<0$			

The theory asserts that the logarithm of R_t should be a zero mean stationary process, or an integrated of order one process. Results of our analysis are contradictory and indicate that real exchange rates are I (1) according to standard univariate unit root tests and I (0) according to the Sims test. However, these results cannot be contrasted. If univariate unit root results are, in fact, true, then I can assert that there is a tendency for the nominal exchange rate and the price ratio to drift apart.

The theory of the PPP also does not allow for multiple unit roots. Therefore, first differences of real exchange rates are checked for stationarity. Results of Dickey-Fuller tests show that first differences of real exchange rates for Japan, France, and Germany are nonstationary. Due to the latter finding, I adopt a Dickey and Pantula strategy of testing for multiple unit roots. Enders (1995) writes that if this strategy yields no evidence of multiple unit roots, one can conclude that the time-series are stationary. I apply this methodology and find no multiple unit roots for real exchange rates applicable to Japan, France, and Germany.

THE COINTEGRATION ANALYSIS

Recall, E, P^d, and P^f represent the logarithms of the price of foreign exchange, foreign price level, and domestic price level respectively. The long-run PPP states that real exchange rates, defined as $E= P^f- P^d$, should be stationary. The unit root tests indicate that these series are non-stationary. Cointegration is an alternative way to check the theory. If the PPP holds then I should expect that the series $\{E*P^f\}$, which is the dollar value of the foreign price level F_t, will be cointegrated with the Canadian price level, P^d. Testing foreign price levels and Canadian price levels in the level and first differenced form indicate that all of these series are I (1)[2]. Autocorrelation functions of price level series in the level form resemble those of non-stationary unit root processes, except for the dollar German price. Standard univariate unit root methods also show that the dollar German price is a stationary process.

In making a choice between the Engle-Granger approach for testing cointegration and the Johansen procedure, one needs to be certain about the distributional properties of error terms. Based on numerous Monte Carlo experiments, researchers agree that the power of the Engle-Granger two-step method is greater than that of the Johansen maximum likelihood approach for testing the existence of cointegration if one of the variables entering the model is not normally distributed. The normality of disturbance terms is tested. Specifically, the Jargue-Bera (J-B) test of normality, as well as the Box-Pierce Q test is performed. Results of these tests show that all of the first differenced variables are not normally distributed. Due to the latter fact, I chose the Engle and Granger approach for testing cointegration.

The long-run PPP, if holds, states that residuals formed from the equilibrium regression[3] are stationary and that the cointegrating vector is $\lambda=1$. The results of equilibrium regressions are given in TABLE 3.

TABLE 3
THE EQUILIBRIUM REGRESSIONS

Country	Coefficient	Value	Stand. Error	t-value	R^2	DW	RSS	Deg. Freedom
US	η	-2.81597	3.07491	-0.91600	0.005951	0.02963	344.9995	183
	λ	0.66396	0.63437	1.047				
UK	η	-5.54772	0.47095	-11.78000	0.667184	0.1116	80.92797	183
	λ	1.86093	0.09716	19.153				
Japan	η	2.45198	0.03584	68.414	0.96262	0.13283	4.69E-02	183
	λ	0.50758	0.00739	68.647				
France	η	-0.75924	0.10831	-7.01	0.9478	0.0661	0.428082	183
	λ	1.28822	0.02235	57.649				

The residuals obtained from each regression equation, called μ_t, were checked for unit roots. Since the residuals from a regression equation have a zero mean and do not have a time trend, the following two equations are applied to residuals from each equilibrium relationship[4]:

$$\Delta\mu_t = \alpha_1 \mu_{t-1} + \varepsilon_{1t} \tag{6}$$

$$\Delta\mu_t = \alpha_1 \mu_{t-1} + \sum \alpha_{i+1} \Delta\mu_{t-i} + \varepsilon_{2t} \tag{7}$$

If α_1 equals to 0, then the null of no cointegration cannot be rejected. The Dickey-Fuller statistic tables are, however, inappropriate here because the residuals used in (6) and (7) are not the actual error terms, but the estimated error terms obtained from running the equilibrium regression. Then I compare the estimated t-values for α_1 from regressions (6) and (7) with the calculated critical values of Engle and Granger[5]. The results of testing residuals from the equilibrium regressions for stationarity are given in TABLE 4.

TABLE 4
TESTING THE RESIDUALS FROM THE EQUILIBRIUM REGRESSIONS FOR STATIONARITY

Country	Estimated regression	Value of $\alpha 1$	Standard Error	t-statistics	BG test compared to critical value	Order of autocorrelation	Phillips-Perron ρ test	Phillips-Perron t test
US	Regression (1)	-0.0144	0.01272	-1.1310	31.76>18.3	10	-3.845	-1.37
	Regression (2)	-0.0157	0.0127	-1.249				
UK	Regression (1)	-0.0679	0.02421	-2.808*	44.28>7.81	3	-13.65	-2.90*
	Regression (2)	-0.09398	0.02427	-3.872*				
Japan	Regression (1)	-0.0716	0.02648	-2.705*	76.34>21.03	12	12.87	0.23
	Regression (2)	-0.0369	0.02558	-1.442				
France	Regression (1)	-0.0371	0.01881	-1.933	15.17>7.815	3	-8.015	-2.11
	Regression (2)	-0.0483	0.01940	-2.489				
*indicates significance at the 5% critical value								

Since in absolute terms the estimated τ-values for both regressions in an application to U.K. exceeds any of the critical values at the 5% significance level, the conclusion is that the estimated residuals are stationary, and, therefore, the U.K. dollar price level and the Canadian price level are cointegrated. Moreover, calculated Phillips-Perron t-test is also statistically significant confirming that the above-mentioned variables are cointegrated. Thus, it is possible to reject the null hypothesis of no cointegration only for the U.K. For all other countries the null hypothesis of no cointegration cannot be rejected and, therefore, it can be concluded that the PPP has generally failed.

Finally, I estimate the U.K./Canadian error-correction model. The lag length is chosen based on results of F-tests and cross-equation likelihood ratio tests. The final versions of error correction models for the U.K. and Canadian price levels during the period of January 1982 to May 1997 are:

$$\Delta F_t = 0.003715\ (0.005053) - 0.062187\ (0.005053)\,\mu_{t\text{-}1} + \varepsilon_{3t} \tag{8}$$

$$\Delta P_t = 0.002977\ (0.000257) + 0.003128\ (0.001226)\,\mu_{t-1} + \varepsilon_{4t} \tag{9}$$

where μ_{t-1} is the lagged residual from the equilibrium regression of the U.K. price level on the Canadian price level; standard errors are given in the brackets. Taking a closer look at the results of the error correction models, one can see that the point estimates in (8) and (9) show a direct convergence towards the long-run equilibrium. For example, when there is a one-unit deviation from the long-run PPP in time period t-1, the U.K. price level falls by 0.062187 units and the Canadian price level rises by 0.003128 units. Both these price changes will work to eliminate any divergence from the long-run PPP in time period t-1. Notice that the speeds of adjustment terms are significantly different from zero for both Canada and the U.K. (the error-correction term is about 2.578 deviations from zero for the U.K. and 2.551 deviations from zero for Canada). This result is consistent with the idea that both countries are large and, therefore, have an impact on movements of the respective exchange rate.

CONCLUSION

In this study, using the time series of exchange rates and consumer price indices, I test the validity of the long-run PPP hypothesis. The five currencies of interest are the U.S. dollar, U.K. pound sterling, German mark, French franc, and the Japanese yen. I attempt two approaches: (1) testing for unit roots of real exchange rates themselves; and, (2) testing the cointegration relationship between the foreign dollar price level and the Canadian price level.

Results of the Sims test suggest that real exchange rates are stationary, lending validity to the PPP hypothesis. In contrary, results of univariate unit root tests show that the PPP has generally failed. Although, alternative tests for unit roots may be more successful in rejecting the null hypothesis of the unit root such as variance ratio tests, MacDonald (1995) asserts that “the degree of mean reversion” remains to be “painfully slow.” The cointegration hypothesis between the foreign and Canadian price levels is confirmed for the U.K. only.

ENDNOTES

1. Results of the unit root testing are available upon request.
2. Results are available upon request.
3. The Engle and Granger equilibrium regression takes the following form: $F_t = \eta + \lambda P_t + \mu_t$
4. In applied econometrics, equation (6) is used only if residuals from the equilibrium regressions are serially uncorrelated. Because I have doubts with regard to whether the errors are white noise, I am also using the augmented form of the test, represented by the regression (7). The unaugmented tests have limited power if residuals are serially correlated.
5. Critical values for cointegration tests are computed from the equation given in J. G. MacKinnon with T=184, “Critical values for cointegration tests,” Cointegrated Time Series: 267-276. For the

regression model with no lags, the 99%, 95%, and 90% confidence levels correspond to critical values of -2.58, -1.94, and -1.62 respectively. For the regression model with lags, the 99%, 95%, and 90% confidence levels correspond to critical values of -3.73, -3.17, and -2.91 respectively.

REFERENCES

Chen, B. (1995). Long-run Purchasing Power Parity: Evidence from Some European Monetary System Countries. *Applied Economics*, 27, 377-383.

Cheung, Y., & Lai, K. S. (1993). Finite Sample Size of Johansen's Likelihood Ratio Test for Cointegration. *Oxford Bulletin of Economics and Statistics*, 55, August, 313-328.

Cochran, S. J. and DeFina, R. H. (1995). Predictable Components in Exchange Rates. *The Quarterly Review of Economics and Finance*, 35, Spring, 1-14.

Enders, W. (1995). Applied Econometric Time-Series. John Wiley & Sons, Inc.

Fung, H. and Lo, W. (1992). Deviations from Purchasing Power Parity. *The Financial Review*, 27, November, 553-570.

Glen, J. D. (1992). Real Exchange Rates in the Short, Medium and Long-run. *Journal of International Economics*, 33, 147-166.

Henricsson, R & Lundback, E. (1995). Testing the Presence and the Absence of Purchasing Power Parity: Results for Fixed and Flexible Regimes. *Applied Economics*, 27, 635-641.

Huang, B. & Yang, C. W. (1996). Long-run Purchasing Power Parity Revisited: a Monte-Carlo Simulation. *Applied Economics*, 28, 967-974.

In, F. & Sugema, I. (1995). Testing Purchasing Power Parity in a Multivariate Cointegrating Framework. *Applied Economics*, 27, 891-899.

MacDonald, R. (1995). Long run Exchange Rate Modelling: A Survey of Recent Evidence. IMF Staff Papers, 42, 437-483.

MacDonald, R. (1992). Long run Purchasing Power Parity: Is it for Real? *The Review of Economics and Statistics,* 3, 690-695.

Sharma, S. C., Mathur, I. & Wong, J. P. H. (1991). Causality in Purchasing Power Parities. *Quarterly Review of Economics and Business*, 31, Spring, 81-89.

Whitt, J. A. (1989). Purchasing Power Parity and Exchange Rates in the Long-run. *Federal Reserve Bank of Atlanta Economic Review*, 74, 18-32.

Zhou, S. (1997). Purchasing Power Parity in high-Inflation Countries: A Cointegration Analysis of Integrated Variables with Trend Breaks. *Southern Economic Journal*, 64, 450-467.