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The Purchasing Power Parity Relationship: Causality and Cointegration Tests Using Korea-U.S. Exchange Rate and Prices

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The paper empirically examines the Purchasing Power Parity (PPP) hypothesis using cointegration and causality tests for Korea-U.S. exchange rate and prices. In conducting empirical tests, quarterly time series data were used covering the period from the first quarter of 1971 to the first quarter of 1996. The cointegration tests indicate the existence of a long-run cointegrating relationship between the Korean exchange rate and the domestic *vis-a-vis* foreign price level. The estimated short-run dynamics suggest that the exchange rate is a stable function of the relative price level with a speed of adjustment of about 24% over a year. This estimated speed of adjustment is somewhat slow but reasonable. Overall, however, the empirical results provide only partial support for the PPP hypothesis for Korea. The causality tests indicate that the causal linkage runs from the exchange rate to relative prices. The latter result is not unusual given that the Korean exchange value was under government control for most of the time period covered in this study.

I. Introduction

Many open economy macroeconomic models impose purchasing power parity (PPP) as a long-run equilibrium condition. In these models, PPP is viewed as a long-run determinant of the foreign exchange rates between/among countries. Because of the importance of PPP in these important class of models, empirical tests of the relationship between exchange rate, domestic prices, and foreign prices assume special significance.

In some theoretical and empirical models of exchange rate determination such as the well known Purchasing Power Parity (PPP) theory, domestic and foreign prices are treated as exogenous variables under the assumption of uni-directional causality running from the price variables to the exchange rate variable. In other models, however, exchange rate is allowed to exert influence on the price variables especially domestic prices in the case of a small open economy. In such an economy, a change in the exchange rate will influence domestic price level via changes in the price of imported goods caused by changes in the exchange rate. However, a change in the exchange rate of a small open economy may not affect the foreign price level. A large open economy

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may produce such an effect. As a result, the causal linkage may follow in the opposite direction. It is also possible to observe causal linkages flowing in both directions, i.e., bi-directional causality (feedback). Thus, one can argue that these causal linkages need to be determined empirically given that economic theory does not give any clear answer to the causality issue. The primary purpose of this study is to empirically examine the causality issue for South Korea involving the variables normally included in the PPP model of the exchange rate.

Many researchers have conducted empirical tests to study the validity of the hypothesized PPP relationship. However, the empirical results from these studies have been mixed and often conflicting. Further, many of these studies have used inappropriate econometric methodologies and/or relatively short time periods to study this long-run relationship and its short-run dynamics. As such, these studies do not adequately explore the long-run relationship existing between/among the exchange rate, domestic prices, and foreign prices implied by the PPP theory without due consideration given to issues such as causality and short-run dynamics within the hypothesized long-run framework. In addition, most of these studies involving PPP have conducted empirical tests using data for only the advanced industrialized countries rather than the developing countries presumably due to lack of time series data of sufficient duration for the latter countries.

The study examines the causal relationship between/among the variables appearing in the PPP relationship, i.e., exchange rate, domestic price level, and the foreign price level. The tests will be conducted using Granger test without corrections for short-run dynamics (standard Granger tests) as well as the more appropriate Granger test which uses the Error Correction mechanism suggested by Engle-Granger (1987). The bivariate causal relationships being examined here focus on causality between the exchange rate and the relative price of domestic *vis-a-vis* foreign goods. The causality tests are expected to detect various possible causal linkages (uni-directional causality, bi-directional causality, or independence (no causality)) between the relevant variables.

As already mentioned, most of the empirical studies involving the PPP theory have conducted tests using data for the advanced industrialized countries. This paper empirically examines the validity of the long-run PPP theory using time series data for Korea-U.S. exchange rate and prices. To our knowledge, no such study exists for these two countries. The study will also overcome various methodological limitations and econometric problems found in the previous studies. More specifically, this paper will utilize advanced econometric techniques such as cointegration tests. The data will also be subjected to extensive diagnostic tests in order to detect the presence of non-stationarity and other econometric problems in the data.

II. Theoretical Framework

In the absence of transportation costs, tariffs and other barriers to trade, and with free trade, the same good should cost the same across national boundaries. Markets enforce the law of one price, because the pursuit of profit tends to equalize prices of identical goods in different countries. Even though short run deviations from PPP may occur, the PPP relationship is expected to hold in the long run. The empirical evidence on the PPP in the long run is mixed. Many studies, such as Edwards (1989), Intal Jr. (1992), Officer (1982), Roll (1979), Frenkel (1981, 1986), Pippenger (1982), Darby (1983), and Frenkel and Mussa (1986) find evidence that are consistent with the hypothesis that deviations from PPP follow a random walk process. This implies that the deviations from PPP are cumulative and permanent such that PPP does not hold. Additional discussion on the empirical evidence on the PPP theory can be found in Levich (1985). The existence of non-tradable sectors and in particular, uneven variation in the ratio of prices of non-tradables to tradables caused by economic growth may cause deviation from PPP. This would be more applicable for developed countries rather than developing economies (McNown and Wallace (1989)).

If the PPP relationship holds, national price levels and the exchange rate should form an equilibrium relationship. If E_t is the exchange rate defined as the domestic price of a foreign currency, P_1 and P_2 are the domestic price index and foreign price index respectively, and t is the time subscript, then the following equation can be used to describe the PPP relationship:

$$E_t = P_{1t} / P_{2t} = R_t, \tag{1}$$

where R_t represents the relative price of the domestic *vis-a-vis* foreign prices. If PPP holds perfectly, the coefficient of R_t will assume a value of one. This will indicate that any change in the exchange rate would reflect changes in the relative price levels of domestic *vis-a-vis* foreign goods. This would indicate that the exchange rate and the relative prices would form a cointegrated system. Thus, the PPP test is really a test of cointegration between the exchange rate and the relative prices.

In reality, however, Equation (1) may not hold perfectly. Factors other than the two prices may affect the PPP relationship. Further, the PPP may deviate in the short-run from its long-run equilibrium path due to various shocks and disturbances. To incorporate these factors, Equation (1) can be rewritten in an empirically testable form as follows:

$$E_t = a + bR_t + u_t, \tag{2}$$

where the coefficient 'a' would reflect the influence of omitted variables, 'b' is the coefficient of the relative price variable, and u_t would reflect any short run deviation from the long-run equilibrium path due to stochastic shocks. Equation (2) can now be used to test empirically the validity of the PPP relationship. In this formulation, PPP would hold under the joint hypothesis that $a=0$, $b=1$ in its strict form and, in a less strict form, under the hypothesis that $b=1$.

In the above equation, the question of causality also arises. Does R_t cause E_t (uni-directional causality), E_t cause R_t (uni-directional causality), both R_t and E_t cause each other (bi-directional causality), or no causal relationship at all (independence).

Although the issue of causality is important, economic theory on this issue is not very clear. A change in R_t will generate pressure for E_t to change. In this case, R_t may cause E_t. However, any change in E_t may also exert pressure on R_t to change so that E_t becomes the causal factor. Finally, both can influence each other. The causality question thus becomes an important empirical question.

III. Empirical Framework

1. Unit Root Tests

For model building, empirical testing, or policy purposes, researchers need to know whether a time series is stationary or non-stationary. A stationary series is generally characterized by a time-invariant mean and a time-invariant variance. The 'stationarity' of each variable can be tested by the following unit root tests: (a) The Augmented Dickey-Fuller test (ADF test); and (b) the Phillips-Perron test (PP test). An elaborate discussion of these tests can be found in Dickey and Fuller (1981) and Phillips and Perron (1988) respectively. If the variables are found to be stationary, then the standard regression method can be applied to estimate the PPP relationship given by Equation (2). If, however, the variables are found to be non-stationary in their levels, then one has to apply the co-integration tests as discussed below.

2. Co-integration Tests: The Engle Granger (EG) Method

If the variables in the PPP model are found to be non-stationary, then we will apply the Engle-Granger (1987) co-integration method. Given that Equation (2) represents a bivariate relationship, the Engle-Granger two-step method seems to be appropriate. This method involves estimating the long-run PPP equation (Equation (2)) by the standard regression method and then the residuals are recovered for co-integration tests. These residuals are then tested for stationarity by applying the ADF and the PP unit root tests. If these tests reveal that the residuals are stationary in their levels, then one concludes that the variables in the long-run model are co-integrated, i.e., they share a common trend even though the variables in the PPP model are individually non-stationary. If the residuals are found to be non-stationary, one would then conclude that the PPP relationship does not hold. This is because, in this case, any short-run deviation from the PPP relationship will be cumulative and permanent and that the variables will not have a common trending relationship.

3. Co-integration Tests: The Johansen-Juselius (JJ) Method

Although Engle-Granger cointegration method could be adequate in a bivariate system, additional evidence about cointegration could be provided by applying the more general technique developed by Johansen (1988, 1991, 1992) and Johansen-Juselius

(1990, 1992). They proposed a maximum likelihood estimation procedure which allows researchers to estimate simultaneously the system involving two or more variables to circumvent the problems associated with the traditional regression methods used in previous studies on this issue. Further, this method is independent of the choice of the endogenous variable, and it allows researchers to estimate and test for the presence of more than one co-integrating vector(s) in the multivariate system. The main features of this method are discussed below.

Following Johansen (1988) and Johansen and Juselius (1990), a VAR representation of the N-dimensional data vector X_t is specified as follows:

$$X_t = + \prod_1 X_{t-1} + \ldots\ldots. + \prod_k X_{t-k} + \delta + \varepsilon_t, \quad t = 1, 2, \ldots\ldots.., T, \qquad (3)$$

where ε_1, ..., ε_T are distributed as N-dimensional i.i.d. normal variables, δ represents a vector of constants, and the X_t is a vector of all the endogenous variables in the system. In this study, the vector X_t is of dimension $N=2$ because it contains two endogenous variables $[E_t, R_t]$' which were defined earlier (Equation (2)).

Now using the notation $\Delta = 1 - L$, where L is the lag operator, the var system represented by (3) can be rewritten as the Error Correction Model (ECM) as follows:

$$\Delta X_t = \prod X_{t-1} + \phi_1 \Delta X_{t-1} + \ldots\ldots. \phi_{k-1} \Delta X_{t-k+1} + \delta + \varepsilon_t, \qquad (4)$$

where $\phi_i = -(I - \prod_1 - \ldots - \prod_i)\ (i = 1, \ldots, k-1)$, and $\prod = I - \prod_1 - \ldots - \prod_k$.

The main focus of the Johansen-Juselius technique is on the parameter matrix $\prod$. The rank 'r' of this matrix $r(\prod)$, where $(0 < r < N)$, will determine the number of co-integrating vectors in the VAR system. If the rank of this matrix is found to be 'r', then there are 'r' linear combinations of the variables in the system that are stationary and that all other linear combinations are non-stationary.

The matrix $\prod$ can be rewritten as $\prod = \alpha\beta'$ where α is speed of adjustment vector (also called weights or loadings) and β is the co-integrating vector. The dimension of α and β are $(N \times r)$ and the system (4) is subject to the condition that $\prod$ is less than full rank matrix, i.e., $r < N$. The procedure boils down to testing for the value of 'r' on the basis of the number of significant eigenvalues of $\prod$. For this purpose, the maximum eigenvalue test (λ_{max}) and the trace test (λ_{Trace}) are applied. The above mentioned test statistics are distributed as χ^2 with appropriate degrees of freedom $(N - r)$ where N is the number of endogenous variables and 'r' is the value of the rank under the null hypothesis. In these likelihood ratio tests, the null hypotheses are accepted if the estimated values are less than the critical values at the appropriate significance level and the degrees of freedom.

The coefficients of the estimated 'α' vector can be interpreted as the weights with which the variables enter the equations in the VAR system. The sign and magnitude of these coefficients will give important information about the short- run dynamics of the system, i.e., its stability as well as the direction and speed of adjustment towards the long-run equilibrium path.

4. Short-run Dynamics Using the Error-Correction Model (ECM)

According to the ‘Granger Representation Theorem’, if the variables in the long-run model are found to be co-integrated, then there must exist an associated error-correction model (henceforth called ECM). This ECM model can then be used to capture any short-run dynamics of the system and it can be used to distinguish between the short-run and the long run relationships among the variables. The procedure involves regressing the first difference of the dependent variable on the contemporaneous and lagged values of the first differences of all these variables including the dependent variable and the lagged residuals from the long-run equilibrium regression.

The parameters of the ECM equation can be estimated by the OLS method since all the variables are stationary because they are in their first difference form. The coefficient of the lagged residual in the ECM equation is of particular interest because it represents the speed of adjustment parameter. The number of lags to be included in the ECM equation is determined such that the errors in this equation become white noise. Appropriate lag length tests has to be performed here to ensure white noise error terms. In view of the trade-off between bias and efficiency of the estimated parameters when the lag orders are changed, Akaike’s (1969) final prediction error (FPE) criterion can be used for selecting the optimum lag lengths.

The value of the speed of adjustment parameter is expected to be less than one in absolute terms for stability of the system and for the variables in the long-run regression to be co-integrated. The sign of this parameter would indicate the direction of the adjustment process. If the system deviates from its long-run path, the sign and magnitude of this parameter would indicate the direction of adjustment and speed at which the variables would adjust in the short-run in order to go back to its long-run equilibrium path.

5. Granger Causality Test Using the ECM Framework

The Granger causality test has been widely used in economics. But the methodology has been subject to criticism, with some authors such as Conway *et al*. (1984) being highly critical of this method. The use of the standard Granger causality test (which does not account for the error correction mechanism) is subject to more criticism than the more advanced Granger causality test based on the ECM model.

On an intuitive level, the standard Granger causality test examines whether past changes in one variable, x, help to explain current changes in another variable, y, over and above the explanation provided by past changes in y itself. If this is true, then one concludes that x Granger causes y; otherwise, x does not Granger cause

y. To determine whether causality runs in the other direction, one simply repeats the above experiment, but with x and y interchanged. Four possible outcomes are possible: (1) Unidirectional causality: x Granger causes y, but not vice versa; (2) Unidirectional causality: y Granger causes x, but not vice versa; (3) Bi-directional causality: x Granger causes y and y Granger causes x; and (4) Independence: neither variable Granger causes the other

The application of the standard Granger test requires that the variables, y and x, be stationary. Since most economic variables are non-stationary in level forms, the standard Granger causality test is conducted using regressions based on appropriately differenced stationary variables. This differencing process throughs away useful long-run information about causal relationships among the variables. Therefore, it is advisable to apply the ECM framework to examine the Granger causality issue instead of the standard Granger method. The Granger causality test using the ECM method is described below.

The methodology developed by Granger (1983, 1986) and Engle and Granger (1987) provides a more sophisticated and more comprehensive test of causality which is applied within the cointegration and error-correction model (ECM). This advanced framework specifically allows for a causal linkage between two variables stemming from a common trend or long-run equilibrium relationship. More specifically, this framework considers the possibility that the long-run information in the data represented by the lagged level of a variable, x, may help to explain the current changes in another variable, y, even if the short-run information in the data given by the past changes in x do not.

The intuition in this more advanced methodology is that if y and x have a common trend, then the current changes in y is partly the result of y moving into alignment with the trend value of x. Such causality may not be detected by the standard Granger test, which examines only short-run information given by the past changes in a variable, x, which help explain current changes in another variable, y. Note that the ECM framework can also be used to detect the possibility of having reverse or even bi-directional causality. As long as x and y have common trends, however, causality must exist in at least one direction within this ECM framework. Thus in the ECM framework, the possibility of finding no causality in either direction - one of the possibilities with the standard Granger test - is ruled out when the variables share a common trend (co-integrated).

In more formal terms, this advanced test is based on error-correction models that incorporate information from the co-integration properties of time-series variables as discussed earlier. In this method, one needs to test whether the residual series from the long-run regression is stationary or not. If the residual series is found to be non-stationary, it implies that there is no meaningful relationship between y and x. As a result, there is no need to proceed further to examine the existence of causal relationship between them. However, if these tests determine the existence of a long-run relationship, then one would proceed with the causality test by forming the error-correction model involving the first differences of the co-integrated non-stationary variables which also includes the lagged residual of the long-run equilibrium model.

The inclusion of this last variable differentiates the error-correction model from the standard Granger causality regression. Thus, by including this term, the ECM model introduces an additional mechanism through which Granger causality can emerge. In this ECM framework, the null hypothesis that 'x does not Granger cause y' is accepted or rejected based on the standard Wald F-test to determine the joint significance of the restrictions under the null hypothesis. If the null hypothesis is rejected, one concludes that x Granger causes y. Notice that the ECM framework allows for the possibility that x Granger causes y, even if the coefficients on lagged changes in x itself are not jointly significant.

To examine whether causality exists in the reverse direction, one needs to estimate the ECM equation with the first difference of the other variable as the dependent variable and then apply the Wald F-test against its restricted version. The null hypothesis that 'y does not Granger cause x' is rejected if the appropriate coefficients including the coefficient of the lagged residual are jointly significant. In this case, y is said to Granger cause x. If both hypotheses are rejected, one then concludes that there exists a bi-directional causality (feedback) between y and x. As already mentioned above, in the ECM framework, the possibility of no causal relationship between y and x is ruled out because of the fact that y and x have a common trending relationship.

It may be noted here that even in the absence of cointegration between two variables, the ECM model can still be estimated to test for short-run standard Granger causality (Bahmani and Payesteh (1993)). In this case, the error-correction term(s) should not be included in the model(s) for estimation purposes.

IV. Data and Variables

Equation (2) is estimated using quarterly time-series data for Korea-US exchange rate, E (won/par. US$) and the consumer price indices of the two countries. Korea is used as the home country and the U.S. is treated as the foreign country. Although Korea has economic interactions with many other countries, it conducts a large amount of economic transactions with the U.S. As a result, it is hoped that the U.S. would act as a good proxy to reflect the rest of the world for Korea in testing the PPP relationship. The data covers the period from the first quarter of 1971 to the first quarter of 1996 with a total of 101 observations. Data for the relevant variables were obtained from the various issues of International Financial Statistics of the IMF. The variables are measured as follows:

EQKUSI = Index of Korea/U.S. exchange rate as a proxy for E_t (quarterly).

CPIQKUSP = Index of the ratio of Korea and US CPI, a proxy for R_t (quarterly).

V. The Empirical Results

1. Unit Root Tests

Table 1 reports the unit root test results using both the ADF and PP tests. ADF test reveals that the null hypothesis of unit root is accepted for both EQKUSI and CPIQKUSP variables in their levels but rejected in their first differences. The phillips-Perron (PP) test also reveals similar results. These variables are thus found to be non-stationary in their levels (or integrated of order one, I(1)) based on both tests. We can thus conclude that the standard regression model is not appropriate in examining the relationship between exchange rate and relative prices. Instead, we have to use the cointegration techniques to uncover the relationships.

Table 1 Results of Unit Root Tests

	ADF Test		Phillips-Perron Test	
Variables	Level	1st-difference	Level	1st-difference
EQKUSI	-1.27	-3.09*	-1.82	-5.56*
CPIQKUSP	-1.38	-2.96**	-1.26	-5.67*

Notes: * significant at the 1% level. ** significant at the 5% level.

2. Co-integration Test: The Engle-Granger Method

The long-run cointegrating relationship given by the theoretical model (Equation (2)) is estimated in linear form by the OLS method and is presented in Table 2. In the long-run equation, the coefficient of the relative price variable is found to be positive and statistically significant at better than 1% level. The relative price variable explains about 80% of the variation of the dependent variable as shown by the R^2 value. However, the coefficient of the relative price variable is found to be 0.73 which is much smaller than its theoretical value of unity under the PPP assumption. Note, however, that since both the variables are non-stationary in their levels, the standard regression interpretation of the coefficients is not valid. This leads us to the Engle-Granger test of the residuals from this regression.

The ADF and the PP unit root tests were applied on the residuals from this long-run regression in order to examine whether the residual series is stationary or non-stationary. The ADF and PP tests on the residuals from the long-run equation (RES) is presented in Table 3 below. The results from both tests suggest that the residuals are weakly stationary. This is because the null of unit root can be rejected only at the 10% level of significance. Based on this result, we can conclude that the exchange rate and the relative price variable are weakly co-integrated, i.e., equilibrium relationship exists between E_t and R_t but the relationship is not very strong.

Table 2 Results of Cointegrating Equation (The Engle-Granger Method)

Variables	Cointegrating Equation
CPIQKUSP	0.73 (20.64)
CONSTANT	-7.46 (2.22)
R^2	0.81
Adj R^2	0.80
SEE	8.45
F	426.10
Prob. of F	0.00
D-W	0.05
Akaike	4.29
Schwartz	4.34

Note: t values are in the parentheses.

Table 3 Results of ADF and PP Tests on the Residuals From Long-run Regression

	ADF Test		Phillips-Perron Test	
Variable	Critical Value	Level	Critical Value	Level
RES	-1.67***	1.62	-1.64***	1.62

Notes: * significant at 1% level. ** sig. at 5% level. *** sig. at 10% level.

3. Co-integration Test: The Johansen-Juselius Method

The results of cointegration tests based on the Johansen-Juselius method is presented in Tables 4, 5, 6, and 8 below. Before applying the Johansen-Juselius method and the characteristics of the $\prod$ matrix, we need to specify the appropriate lag length 'k' of the VAR system so as to make the residuals uncorrelated and homoskedastic. Akaike Information Criterion and the Schwartz Criterion were used in determining the appropriate lag lengths. In this data set, an optimal lag length of $k=2$ was sufficient to make the residuals uncorrelated and homoskedastic. Table 4 presents the λ_{max} and λ_{Trace} test statistics for the model along with their 90% critical values. This table shows that the null hypothesis of $r(\prod)=0$ is clearly rejected by both the λ_{max} and λ_{Trace} test statistics at the 10% significance level. The null hypothesis that $r(\prod)$ is less than or equal to one cannot be rejected by the two test statistics. So, it can be concluded that there is only one co-integrating vector $(r=1)$ in the VAR system. Compared to the Engle-Granger results, this result provides a much stronger support for the presence of long-run cointegration relationship between the exchange rate and the relative price variables.

Table 4 Determination of the $r(\prod)$ based on λ_{max} and λ_{Trace} test statistics

Eigenvalues (λ_i)	λ_{max} statistic	λ_{Trace} statistic	Null Hyp: Ho: r	critical value λ_{max} (90)	critical value λ_{Trace} (90)
0.1227	12.96	13.54	0	10.60	13.31
0.0059	0.59	0.59	1	2.71	2.71

4. Residual Analysis

Given the above selection of a single co-integrating vector and the deterministic components model (trends in the levels), diagnostic tests on the residuals from all the endogenous variables in the VAR system are presented in Table 5. This table reports some descriptive statistics as well as several univariate tests on the residuals of all the endogenous variables. The descriptive statistics include the mean, standard deviation, skewness, and kurtosis measures of the residuals from each equation of the VAR system. The two univariate tests on the residuals are: (a) the LM (Lagrange Multiplier) tests on residuals obtained for each of the equations of the VAR system using an ARCH (Autoregressive Conditional Heteroskedasticity) process of appropriate lag order in order to test for the hypotheses that the residuals are uncorrelated and homoskedastic. (b) the second univariate test is the test for normality of the residuals using Doornik-Hansen (1994) version of the Shenton-Bowman (1977) test for each of the equations in the VAR system. This table also reports the R^2 values from each equation in the system.

This table shows that the degree of skewness does not seem to be high except for the exchange rate variable. Excess Kurtosis appears in the exchange rate variable as well. These indicate that the residuals, especially from the exchange rate equation, may not follow a normal distribution. The univariate Doornik-Hansen normality tests reported in this table provide evidence of deviations from normality for the exchange rate variable but not for the relative price variable (evaluated at the 5% level of significance). This deviation from normality, however, does not render the co-integration tests invalid. Similar deviations from normality were observed by Johansen and Juselius in two of their empirical papers (1990, and 1992).

Table 5 Diagnostic Tests for the n.i.i.d. Assumption for the Residuals

Variables	Mean	St. Dev.	Skewness	Kurtosis	Normality	ARCH(2)	R-squared
ΔEQKUSI	0.00	1.50	2.07	12.89	37.59	0.341	0.35
ΔCPIQKUSP	0.00	1.03	0.26	4.27	8.61	0.375	0.43

Notes: or ARCH (2), the critical value at the 5% level with 2 degrees of freedom is 5.99. For normality, the critical value at the 5% significance level is 15.507.

For carrying out the co-integration analysis, a more important issue is whether the residuals are uncorrelated and homoskedastic. These are tested by the LM tests on the ARCH(2) process and the test results are given in Table 5. The order of 2 for the ARCH process is determined by the optimal lag structure which was earlier determined to be of order $k=2$. The LM tests on each equation suggest that the residuals are uncorrelated as well as homoskedastic in all the equations of the VAR system. Based on this result, one can proceed with the interpretation of the co-integration test results as follows.

5. Estimated Long-run Relations and Short-run Dynamics

Based on the existence of a single co-integrating vector, maximum likelihood (ML) estimate of the co-integrating vectors (normalized on EQKUSI) is presented in Table 6.

Table 6 ML Estimates of the Co-integrating Vector (Normalized on EQKUSI)

Variables	Co-integrating vector (β)	$\chi^2(1)$	5% Critical Value ($\chi^2(1)$)
EQKUSI	1.00	-	-
CPIQKUSP	-0.58	7.12	3.84
CONSTANT	6.26	-	-

Notes: $\chi^2(1)$ statistics are derived by imposing exclusionary restrictions on corresponding explanatory variables (β); Constants were not included in the cointegration space during estimation of the co-integrating vector (β).

It also reports the χ^2 statistics for long-run exclusionary restrictions for the explanatory variable of the model. These statistics can be used to make inferences about the significance of the different explanatory variables in the two equations. The results show that the null hypothesis of long-run zero restriction is rejected for the relative price variable at 5% level of significance. For comparison purposes, the long-run equilibrium exchange rate equation based on the estimated coefficients obtained from the Engle-Granger and the Johansen-Juselius methods are given in Equations (5) and (6) respectively as follows:

$$EQKUSI = -7.46 + 0.73\ CPIQKUSP, \tag{5}$$

$$EQKUSI = -6.26 + 0.58\ CPIQKUSP. \tag{6}$$

The results show that, in both cases, the coefficient of the relative price variable falls short of its theoretical value of unity, more so from the Johansen-Juselius method than the Engle-Granger method. Thus, while there exists a long-run relationship between the exchange rate and relative price variables, the relationship is far from being perfect. This weakness in the empirical result could be due to errors in the measurement of the relevant variables as well as due to possible influence of other variables (such as productivity shocks, institutional changes, or policy reforms) affecting the equilibrium exchange rate which were not captured in this paper.

6. Short-run Dynamics and the ECM Estimates

Given that the variables are co-integrated, one can proceed to estimate the ECM model. The results from the short-run dynamics based on the Engle-Granger error-correction model is presented in Table 7 while those based on the Johansen-Juselius method is given in Table 6, 8. In estimating this model, two lags for the explanatory variable were found to be sufficient to make the residuals to become white noise. In the Engle-Granger framework, the coefficient of the lagged residual (RES(-1)) in Table 7 is of particular interest because it represents the speed of adjustment as well as stability of the system. The absolute value of the coefficient is found to be less than one which indicates that the system is stable. However, the coefficient value is quite small which indicates that about 6% of any deviation from the long-run path is corrected within a quarter which translates into about 24% adjustment per year. The result obtained from the Johansen- Juselius method (Table 8) is found to be 28% per year, a result which is very similar to the one obtained from the Engle-Granger method. The speed of adjustment seems to be reasonable given the structural characteristics (bottlenecks, rigidities, and informational gap) facing any developing economy such as Korea.

Table 7 The Engle-Granger Error Correction Model Estimates

Variables	Coefficient	t-value	Probability
$DCPIQKUSP_{t-1}$	-0.30	-2.30	0.0237
$DCPIQKUSP_{t-2}$	-0.05	-0.34	0.7318
$DEQKUSI_{t-1}$	0.45	4.56*	0.0000
$DEQKUSI_{t-2}$	0.20	1.96**	0.0537
RES_{t-1}	-0.06	3.12**	0.0024
Const.	0.43	2.22	0.0285
R^2	0.35		
Adj R^2	0.32		
SEE	1.51		
F	9.99		
Prob. of F	0.00		
D-W	1.97		
Akaike	0.88		
Schwartz	1.04		

Note: t-values are in parentheses. * Significant at 1% level. ** Significance at 5% level.

Table 8 Short-run Dynamics and Speed of Adjustment Based on the Johansen-Juselius Method

Variables	Speed of adjustment (α)	t-values
ΔEQKUSI	0.55	6.33
ΔCPIQKUSP	-0.28	-2.05

7. Granger Causality With and Without the Error Correction Model

As mentioned earlier, Granger causality test can be performed without error correction as well as with correction for error term using the ECM framework. Although the latter procedure is more appropriate when the variables in the long-run model are individually non-stationary in their levels but have a common trend (cointegrated), we decided to report here causality tests under both scenarios for comparison purposes. Table 9 reports Wald test results based on the F-test. The calculated as well as the theoretical F values under the null hypotheses under both scenarios are presented in this table.

Table 9 Wald F-Test For Granger Causality: With and Without Error Correction

Calc. F	F at 5% (1%)	D.F. (Num)	D.F. (Denom)	Accept/Reject
A. Granger Causality Without Error Correction				
Ho: CPIQKUSP does not Granger cause EQKUSI				
1.23	3.12(4.85)	2	93	Accept Ho
Ho: EQKUSI does not Granger cause CPIQKUSP				
1.67	3.12(4.85)	2	93	Accept Ho
B. Granger Causality With Error Correction				
Ho: CPIQKUSP does not Granger cause EQKUSI				
2.47	2.72(4.01)	3	92	Accept Ho
Ho: EQKUSI does not Granger cause CPIQKUSP				
4.14*	2.71(4.01)	3	92	Reject Ho

Note: * Significance at 1% level.

The standard Granger test without the error-correction term shows that the null hypothesis ‘CPIQKUSP does not Granger cause EQKUSI’ could not be rejected. Similarly, the reverse null hypothesis ‘EQKUSI does not Granger cause CPIQKUSP’ could not be rejected either. So, this test would lead one to conclude that the two variables in the PPP model, the exchange rate and the relative price variable does not Granger cause each other. In other words, they appear to be independent.

However, the application of the more appropriate and advanced Granger test with error-correction shows a different result. This test shows that the null hypothesis of ‘CPIQKUSP does not Granger cause EQKUSI’ could not be rejected at 5% level of significance. However, the reverse null hypothesis ‘EQKUSI does not Granger cause CPIQKUSP’ is rejected at the 1% level of significance. Thus, the latter test shows uni-directional Granger causality flowing from the exchange rate variable to the relative price variable. This result seems to be reasonable for a developing country like Korea where the exchange rate is to a great extent controlled and adjusted by government decree rather than by market forces. For Korea, it does appear that its nominal exchange rate affects (causes) the relative price variable.

VI. Concluding Remarks

In this paper, we tested the PPP hypothesis for Korean-U.S. exchange rate and prices using quarterly data for the period 1971 to 1996. We applied the Dickey-Fuller and Phillips-Perron tests to examine for the non-stationarity of data. Both tests indicate that the nominal exchange rate and the relative price level are non-stationary in their levels but stationary in their first differences. The study then applied the Engle-Granger two-step method of cointegration as well as the Johansen-Juselius method of cointegration in order to determine whether there is any long run relationship between the Korea-U.S. bilateral exchange rate and the relative prices in the U.S. and Korea. The results from both cointegration tests lend support for the PPP hypothesis as a long run equilibrium condition. Stronger support came from the Johansen-Juselius method than the Engle-Granger method. However, the onserved long-run equilibrium relationship was far from being perfect in the sense that the estimated value of the coefficient of the relative price variable was found to be lower than its expected value of unity. The weakness in the empirical result could be due to errors in the measurement of the relevant variables as well as due to possible influence of other variables (such as productivity shocks, institutional changes and policy reforms, transaction costs, and the existence of substantial non-tradable sectors, among others, factors which were not captured in this paper) affecting the equilibrium exchange rate. The measurement error can occur because of the dissimilarity in the basket of goods captured by CPI's in the two countries or in the difference in the weights assigned to different goods in the two countries.

Finally, the ECM estimates suggest that the exchange rate is a stable function of the relative prices with a speed of adjustment of about 24% over a year. This estimated speed of adjustment is somewhat slow but reasonable. The Granger causality test without error correction shows that the exchange rate and the relative price variables are not causally linked with each other. However, the more appropriate and advanced Granger causality test with error correction shows uni-directional causality flowing from exchange rate to relative prices but not vice versa. This causality result is not unexpected given that the exchange rate in Korea has been under government control for most of the time period covered in this study.

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