JOURNAL OF ECONOMIC DEVELOPMENT
Volume 29, Number 1, June 2004

THE MEXICAN PESO AND THE KOREAN WON REAL EXCHANGE RATES: EVIDENCE FROM PRODUCTIVITY MODELS

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Using the U.S. as benchmark country, Korean data from 1970:1 to 2000:4 and Mexican data from 1983:1 to 2000:4 are decomposed into traded and non-traded sectors. We find that the traditional purchasing power parity (PPP) model performs remarkably well for the Peso and that the productivity model appears adequate for the Peso but not for the Won. As Mexican relative traded goods productivity rises, the nominal Peso appreciates (coefficients between -2.03 and -2.16). Conversely, as U.S. relative traded goods productivity rises, the Peso depreciates (coefficients between 2.06 and 2.48). Although predicting correctly the direction of change, such large magnitudes suggest only partial support for the theoretical mechanism in Mexico. Coefficients with contrary signs obtained in Korea may indicate competing models (neoclassical or Ricardian) are more appropriate to capture the relationship between productivity and exchange rates.

Keywords: Cointegration, Non-traded Goods, Traded Goods, Traditional PPP, Productivity Models
JEL classification: F11, F31

1. INTRODUCTION

The econometric approach to productivity differentials and real exchange rates is based on the following conjecture: if a long-run equilibrium exists, productivity innovations explain permanent changes in real exchange rates. A representative study of this line of research is Strauss (1996) who finds that: i) increases in the domestic productivity of traded goods (relative to non-traded) appreciates the real exchange rate in all six industrial economies studied, and ii) increases in the foreign productivity of traded goods depreciates the real exchange rate in four of the economies. The theoretical idea is of course much dated, going back at least to works of the sixties (Balassa (1964)

* The authors wish to thank an anonymous referee of this journal for pointing out shortcomings in a previous version of this article. The usual disclaimer applies.

and Samuelson (1964)). Hsieh (1982), in one of the first empirical implementations of the productivity-based model, estimates the basic model under German and Japanese annual data from 1954-1976 against their major trade partners.

The results in Hsieh (1982) are now viewed with skepticism, especially because time series methods have been extended in many ways during the last 20 years. The results in Strauss (1996) perhaps lack power as well, due to its approach under annual data covering the period 1960-1990. Moreover, as emphasized by Froot and Rogoff (1995), the field of real exchange rates is especially vulnerable to survivorship bias. This is so because, due to data limitations, evidence is almost exclusively established for industrial economies. Studies in this field that apply original econometric methods under data from industrial economies include: Mark (1990), Cheung and Lai (1993), Chen (1995), and Costa and Crato (2001). On the Balassa-Samuelson effect, in particular, Canzoneri *et al.* (1999) and Faria and León-Ledesma (2003) apply panel cointegration and the bounds test approach, respectively, to industrial economies.

Less developed countries (LDCs) or newly industrialized countries (NICs) are less frequently explored. It is true that empirical studies of purchasing power parity (PPP) are now often found under various time series methods, including cointegration, for such countries. Examples include: McKnown and Wallace (1989) on four high inflation economies, Mollick (1999) and Alves *et al.* (2001) on Brazil in the very long run, Salehizadeh and Taylor (1999) for several emerging economies, and Choudhry (2000) for Eastern European countries. A related set of studies on LDC countries is based on the econometrics of trend breaks, of which Mahdavi and Zhou (1994) and Zhou (1997) are typical examples.

None of these studies, however, has focused on the productivity-model of the real exchange rate as put forward by Hsieh (1982). The most likely reason for the scarcity of research is data availability. Despite advances in data gathering and technology, LDCs still suffer from severe data limitations. This study attempts to remedy this problem, employing a carefully trimmed dataset for Korea and Mexico, using the U.S. as benchmark. Using country-specific data sources in the three countries, we define the *traded goods sector* as manufacturing and the *nontraded goods sector* as the sum of seven broad services areas: electricity, gas and water; construction; wholesale and retail sale, restaurants and hotels; transport, storage and communication; financial services and insurance; community, social and personal services; and government services. This division is backed by OECD guidelines and has been used before for industrial economies by Strauss (1996).

The empirical exploration of the productivity model for the Korean and Mexican economies is straightforward. Suppose that both countries experience higher productivity growth in the traded sector than in the non-traded sector, which is an assumption entirely consistent with the data as will be shown below. The price of traded goods in these countries remains constant due to the law of one price on traded goods. Higher productivity in the traded goods sector will lead to higher wages paid to its workers, which will imply higher wages in the non-traded good sector due to labor mobility. However, because the productivity gains in the non-traded good sector are smaller than those in the traded good sector, firms in the non-traded good sector will have to raise prices to absorb the wage increase. This will bring about a rise in the overall price level domestically. If the foreign (say, U.S.) price level is unchanged, the rise in domestic prices will translate into a real exchange rate appreciation. Conversely, slower productivity growth in the traded good sector leads to a real exchange rate depreciation.

In order to reconsider the sector productivity-based model for Korea and Mexico, we borrow from the methodologies of Strauss (1996), Canzoneri *et al*. (1999) and Alquist and Chinn (2002). This research route has the advantage of presenting, first, the *traditional PPP model* with the spot rate adjusting one by one with home and foreign price levels. It then moves to the *standard productivity model*, in which the real exchange rate is driven by productivity differentials in each country. Rejections of the former are widespread in the literature. Strauss (1996), for example, attribute them for the six economies studied to "measurement errors" or innovations in productivity differentials. The standard productivity model, on the other hand, has found mixed support across quarterly data studies (Canzoneri *et al*. (1999), Alquist and Chinn (2002)) and broad support across annual data studies in Strauss (1996) and in the non-parametric approach of Tille *et al*. (2001).

Combining the definition of the real exchange rate and the standard productivity model leads to what may be called the *augmented productivity sector model*, so far not estimated for LDCs. This paper aims to remedy such gap in evidence, on a quarterly data basis, for the economies of Korea and Mexico. We find first that the traditional PPP model performs remarkably well for the Mexican peso. Not only cointegration is found under both Johansen and Stock and Watson methodologies, but also the coefficient of the nominal exchange rate with respect to price differentials in Mexico varies in a narrow range from 0.94 to 1.04. The standard productivity model, however, is strongly rejected for both countries, while the augmented productivity model predicts well the standard theoretical implications of the Mexican Peso against the USD. As Mexican traded goods productivity rises, the nominal exchange rate appreciates. Conversely, as U.S. traded goods productivity rises, the nominal exchange rate depreciates, and the effect of price differentials on the exchange rate is close to 1. Nevertheless, the coefficient of the productivity differentials is found to be larger than expected. Related evidence in Maeso-Fernandez *et al*. (2001) and Alquist and Chinn (2002) support coefficients between -4 and -5 on productivities in recent research on the euro.

A likely reason for the failure of the model is that, in Korea, the relative traded goods productivity gap grows overall but suffers a slowdown in the mid to late 80s. This pattern contrasts to the monotonically increasing traded goods productivity gap in Mexico that may have been responsible to the negative relationship between traded goods productivity and the exchange rate. From a theoretical perspective, coefficients with contrary signs obtained in Korea may indicate competing models (neoclassical or Ricardian) are more appropriate to capture the relationship between productivity and exchange rates.

The remainder of the paper is organized as follows. Section 2 presents the derivation of the models to be estimated and Section 3 discusses the data. Section 4 summarizes the major findings and Section 5 reviews the results and suggests extensions for further work.

2. THE MODELS

According to the purchasing power parity (PPP) doctrine, the nominal exchange rate (S), expressed as the domestic currency price of one unit of foreign exchange adjusts to movements in domestic (P) and foreign (P^*) price levels. The real exchange rate (Q) is defined by the nominal exchange rate corrected to movements in domestic and foreign price levels, which results, in logarithmic form:

$$s = k + p - p^* \tag{1}$$

$$q \equiv s + p^* - p \tag{2}$$

where k is a constant equal to zero when absolute PPP holds and different from zero when some form of relative PPP holds. A large set of studies surveyed by Froot and Rogoff (1995) explores that temporary deviations from PPP imply q follows a covariance stationary process. If there is no long run relationship, there is no trend for prices to return to levels dictated by PPP. If PPP does not hold, q has a unit root and deviations from PPP are permanent.

Due to impossibility of arbitrage-based transactions, PPP is imposed on the traded goods (T) sector:

$$p_T = p_T^* + s \tag{3}$$

The general price level, however, is composed of traded and non-traded (NT) goods as follows, with respective shares given by α and α^*:

$$p = (1-\alpha)p_T + \alpha p_{NT} \tag{4a}$$

$$p^* = (1-\alpha^*)p_T^* + \alpha^* p_{NT}^* \tag{4b}$$

Substitution of these equations into (2) yields the equivalent expressions:

$$q = -\alpha(p_{NT} - p_T) + \alpha^*(p_{NT}^* - p_T^*) \tag{5}$$

Equation (5) suggests that q depends on the relative price of nontradables in the two economies. A rise in the relative domestic price of nontradables implies an appreciation of the real exchange rate, while a rise in the foreign relative price of nontradables causes a depreciation of the real exchange rate.

The differential productivity model proposed by Hsieh (1982), based on the Balassa-Samuelson paradigm, is a 2-country model with one factor (labor), in which its supply is fixed at the aggregate. Labor, however, may move within the two sectors, which leads to wage equalization across sectors. Suppose now that the marginal product per worker (MPL) in the 2 sectors is given by A_T and A_{NT}. Price competition leads to:

$$P_T = W / A_T\,,\quad P_{NT} = W / A_{NT}\,,\quad P_T^* = W^* / A_T^*\,, \text{ and } \quad P_{NT}^* = W^* / A_{NT}^* \tag{6}$$

Due to measurement difficulties associated with MPL, we replace it by the average product per worker as in Hsieh (1982). Among the justifications provided in Canzoneri *et al*. (1999) for this shortcut, the most important is perhaps that this precludes data on (sector) capital stock, requiring information on (sector) employment or value added. Replacing (6) into (5) leads to the **standard productivity model** and to the **augmented productivity model**, respectively:

$$q = -\alpha(a_T - a_{NT}) + \alpha^*(a_T^* - a_{NT}^*) \tag{7}$$

$$s = (p - p^*) - \alpha(a_T - a_{NT}) + \alpha^*(a_T^* - a_{NT}^*) \tag{8}$$

When $(a_T - a_{NT})$ grows, the relative price of nontradables $(P_{NT} - P_T)$ grows. By (5), q falls, ensuing a real exchange rate appreciation. If the data generation process is non-stationary, cointegration analysis searches a long-run equilibrium relationship within the vectors below:

$$Z1 = [s,\ p - p^*] \tag{9a}$$

$$Z2 = [q,\ a_T - a_{NT},\ a_T^* - a_{NT}^*] \tag{9b}$$

$$Z3 = [s,\ p - p^*,\ a_T - a_{NT},\ a_T^* - a_{NT}^*] \tag{9c}$$

The vector Z1 is the **traditional PPP model** with the spot rate adjusting one by one with price levels at home and abroad. The vector Z2 contains the **standard productivity model**, in which the real exchange rate is ultimately driven by productivity differentials in each country, and vector Z3 is another representation of the theory, in what we call the **augmented productivity model,** since now both PPP and relative productivities are considered. Positive evidence on Z2 and Z3 suggests the Balassa-Samuelson framework is operative. If, in particular, a linear combination of (9c) is stationary, there is a cointegration relationship among the spot rate, relative prices, and productivity differentials in the two countries.

3. THE DATA

The data consists of annual and quarterly series of South Korea and the United States for the period 1970-2000 and Mexico for the period of 1983-2000. The data set is created with several series taken from country-specific data sources as follows. For Mexico, from the Instituto Nacional de Estadística Geografia e Informática (**INEGI**: http://www.inegi.gob.mx). For South Korea, from the National Statistic Office of Korea (**NSOK**: http://www.nso.go.kr). For the U.S., from the Bureau of Economic Analysis (**BEA**: http://www.bea.doc.gov), and from the Bureau of Labor and Statistics (**BLS**: http://stats.bls.gov).

In order to calculate traded and nontraded average labor productivities, we classify sector product using a methodology similar to Strauss (1996), who used the Organization for Economic Cooperation and Development (OECD) classification. The traded goods sector includes all of manufacturing and the nontraded goods sector includes all of the following services: electricity, gas and water; construction; wholesale and retail sale, restaurants and hotels; transport, storage and communication; financial services and insurance; community, social and personal services; and government services.

Figures 1 and 2 contain the most important series for Korea and Mexico, respectively. The traded and nontraded average labor productivities (A_{NT} and A_T of Section 2) are calculated by dividing each of the total production by sector in constant prices by the total (full and part time) employment of the respective sector. The sector productivities in a given country appear in the figures as *lnprodkr*, *lnprodmx*, and *lnprodus*. It can be seen a modest slowdown in Korean relative sector productivity during the 80s and that the 90s are years of steady growth in productivity. This pattern contrasts to Mexican relative traded goods sector productivity growth, which is monotonically increasing. In the U.S., relative productivity across sectors displays a fairly well behaved growing trend.

The nominal Won and Mexican Peso exchange rates with respect to the U.S. dollar (USD) are called, in logarithms, *lnnerkr* and *lnnermx* in Figures 1 and 2. The logarithm of the real exchange rate with USD as the foreign currency is simply called q. The consumer price index (P), and the price indexes of each sector in Mexico and in South Korea (P_{NT} and P_T) are obtained from the same databases of each country mentioned above.

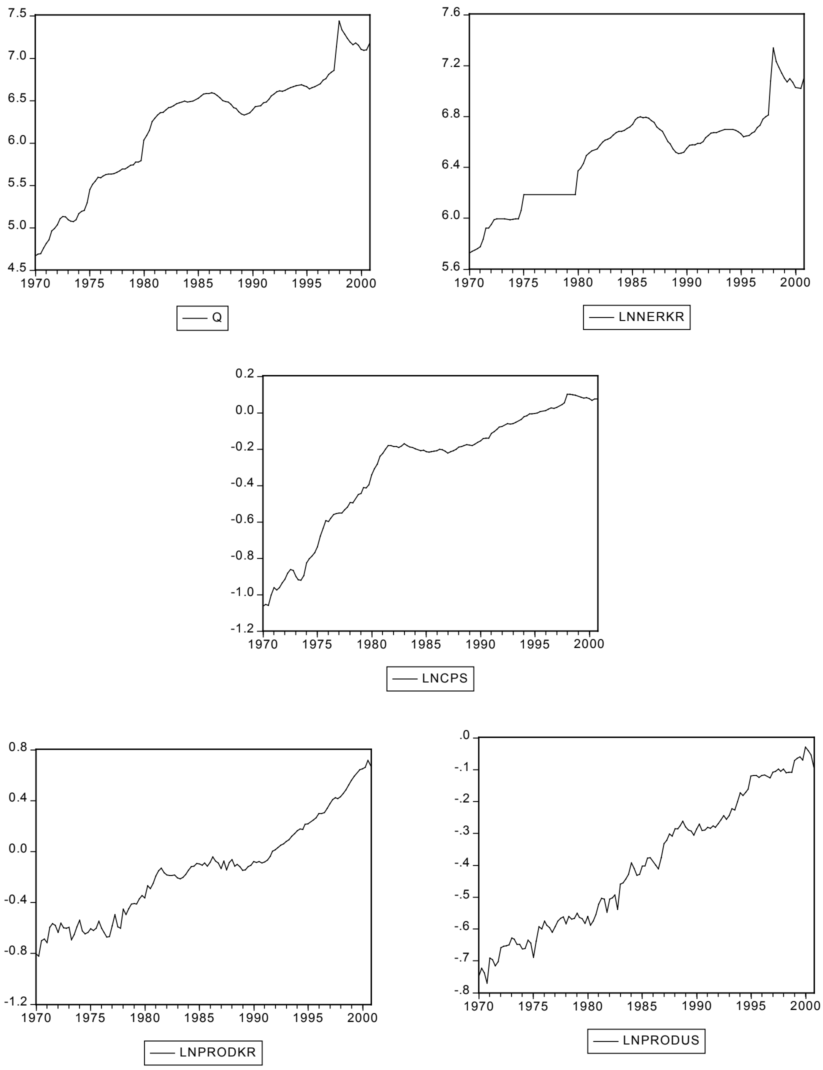

Figure 1. Korean series from 1970.1 to 2000:4: *q* (the log of the real exchange rate), *lnnerkr* (the log of the nominal exchange rate), *lncps* (overall price differentials between Korea and the U.S.), *lnprodkr* (productivity differentials between tradable and non-tradable sectors in Korea), and *lnprodus* (productivity differentials between sectors in the U.S.)

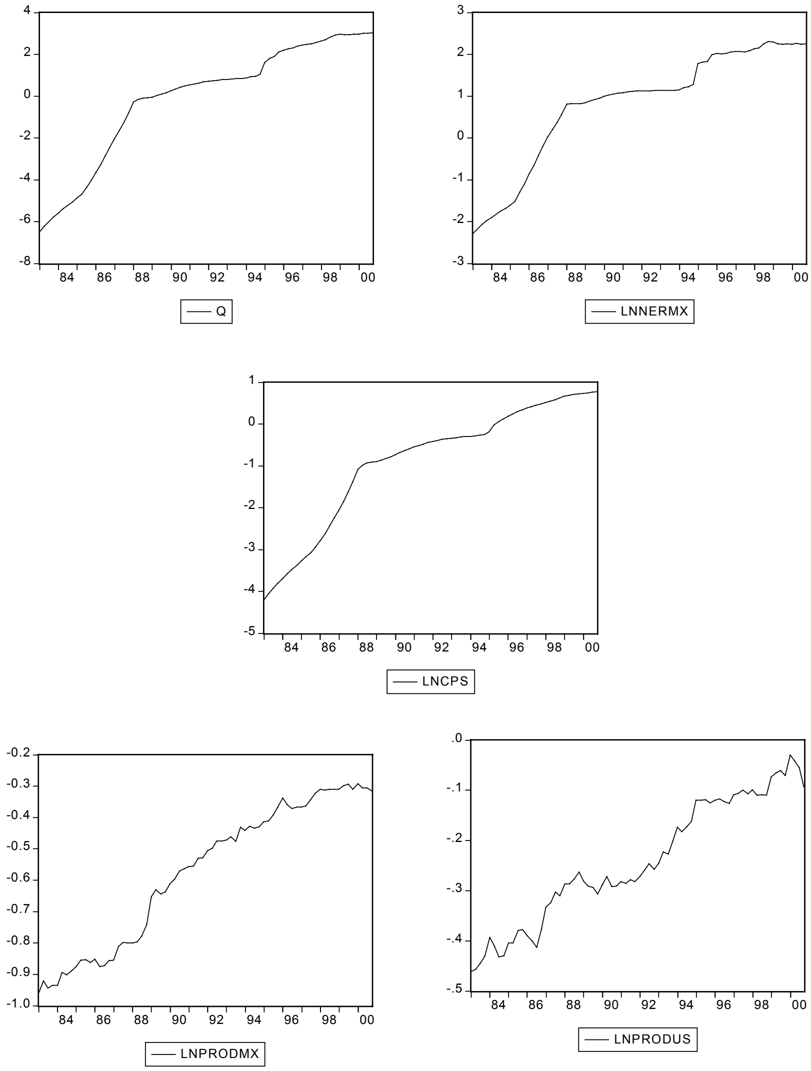

Figure 2. Mexican series; 1983.1 to 2000:4: *q* (the log of the real exchange rate), *lnnermx* (the log of the nominal exchange rate), *lncps* (overall price differentials between Mexico and the U.S.), *lnprodmx* (productivity differentials between tradable and non-tradable sectors in Mexico), and *lnprodus* (productivity differentials between sectors in the U.S.)

The U.S. CPI is obtained from the BLS. The difference, in logarithms, between each country's price level and the U.S.'s is called *lncps*. For all three countries, CPI and price indexes of nontradable and tradable sectors are on a 1995 basis. Employment is in thousands of people for all three countries. For the three countries, PIB-nontradable and PIB-tradable are in (billons of wons, thousands of pesos, or millions of USD) 1995 constant prices.

The quarterly data for Mexico and Korea are originally in non-seasonally adjusted (*nsa*) form, while the U.S. series are seasonally adjusted (*sa*). To use them together, we convert the *nsa* series to *sa*, employing the estimation method of X-12 ARIMA with holiday and trading day adjustment, which turns out to be the method employed by the U.S Bureau of the Census.

For the construction of sector-based productivities, the U.S. GDP by industry does not exist on a quarterly basis as defined above. It is possible, however, to see that U.S. National Income by industry is appreciably different than GDP by industry in levels, but the growth rates are very close. Therefore, in order to create quarterly U.S. GDP by industry (real and nominal), an interpolation routine is adopted converting annual data to quarterly data with the growth rates of the seasonally adjusted quarterly National Income (without capital consumption adjustment). This is the method recommended by BEA.

4. RESULTS

4.1. Preliminary Results

Consider first the unit root evidence in Table 1 for the period 1970:01 to 2002:02 for Korea and for the period 1983:01 to 2002:02 for Mexico. Three types of unit root tests are used. The first is the usual Augmented Dickey-Fuller (ADF) test. We employ the sequential approach suggested by Ng and Perron (1995) for choosing the number of lags in the estimating equations that appear in parenthesis close to the reported ADF figure. We also employ the Elliott, Rothenberg and Stock (ERS) (1996) generalized least squared (DF-GLS) test, which is also computed under the null that the series is non-stationary. Finally, we report the results of the Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) (1992) test, in which the null hypothesis becomes the stationary series.[1]

[1] For the KPSS test, Table 1 contains values calculated under lag-length (L) truncation parameter equal to 4 and the Bartlett kernel is used for spectral estimation method. As a robustness check, we choose different choices of L in the KPSS test using L of 0, 4 and 13. These three choices match precisely the original choices of KPSS for lag-length, in which Monte Carlo simulations show that size distortions appear as L increases (KPSS (1992, p.170)). The results using $L=0$ and the ones reported in Table 1 are broadly consistent. If we did not correct for error autocorrelation (and had taken $L=0$), we would be assuming that iid errors are plausible under the null (of stationarity around a deterministic trend), which is not justified

Table 1. Unit Root Tests (Quarterly)
Korea and USA: 1970.1-2000.4 ; México: 1983.1-2000.4

Unit Root Test	*q*	*lnner*	*lnpnt*	*lnpme*	*lncpi*
ADF	**Series in Levels [statistic (*k*)] for tests with constant and trend**				
Korea	-2.38(3)	-2.63(3)	-2.92(1)	-1.90(0)	-1.76(1)
USA			-2.37(1)	$-3.18(4)^{*}$	
Mexico	-1.65(1)	-2.27(3)	-2.68(1)	-0.57(0)	-1.83(1)
DFgls					
Korea	-1.51(1)	-2.15(1)	-1.41(1)	-2.03(0)	-0.65(1)
USA			-1.51(4)	$-3.15(4)^{**}$	
Mexico	-0.99(1)	-1.65(3)	-1.60(1)	-0.94(0)	-1.32(1)
KPSS					
Korea	0.44^{***}	0.30^{***}	0.50^{***}	0.23^{***}	0.52^{***}
USA			0.24^{***}	0.17^{***}	
Mexico	0.31^{***}	0.28^{***}	0.12^{*}	0.28^{***}	0.33^{***}
ADF	**Series in First Differences [statistic (*k*)] for tests with constant only**				
Korea	$-7.18(0)^{***}$	$-7.43(1)^{***}$	$-15.79(0)^{***}$	$-10.31(1)^{***}$	$-6.65(0)^{***}$
USA			$-8.07(3)^{***}$	$-9.99(1)^{***}$	
Mexico	$-3.07(0)^{**}$	$-4.67(0)^{***}$	$-6.23(0)^{***}$	$-8.11(0)^{***}$	-2.14(0)
DFgls					
Korea	$-7.21(0)^{***}$	$-7.59(0)^{***}$	$-4.88(2)^{***}$	-1.38(8)	$-6.61(0)^{***}$
USA			$-14.00(0)^{***}$	$-10.55(0)^{***}$	
Mexico	$-2.68(0)^{***}$	$-1.90(2)^{*}$	$-5.97(0)^{***}$	$-3.16(1)^{***}$	-1.55(0)
KPSS					
Korea	0.250	0.10	0.26	0.15	0.74^{***}
USA			0.12	0.06	
Mexico	0.70^{**}	0.57^{**}	0.22	0.33	0.78^{***}

Notes: The variables are defined as follows: *q* stands for the log of the real exchange rate; *lnner* stands for the log of the nominal exchange rate; *lnpnt* stands for the log of the relative price of nontradables; *lnpme* stands for the log of traded to nontraded sectors productivity; *lncpi* stands for the log of the relative general price level. ADF (*k*) refers to the Augmented Dickey-Fuller *t*-tests for unit roots, *k* is the selected lag length, DF gls (*k*) refers to Elliott-Rothenberg-Stock Dickey Fuller GLS test statistic for unit root, and KPSS refers to the Kwiatkowski-Phillips-Schmidt-Shin test. For the series in levels, the ADF (*k*), DF gls (*k*), and KPSS of each entry are estimated with a constant and trend as suggested by visual plots in Figure 1. For the unit root tests in first-differences the test has only a constant. In the ADF and DF-gls tests, *k* is determined by the Campbell-Perron's lag length selection procedure developed formally in Ng and Perron (1995). The method starts with an upper bound, $k_{max} = 8$, on *k*. If the last included lag is significant, choose $k = k_{max}$. If not, reduce *k* by one until the coefficient of the last lag becomes significant (we use the 5% value of the asymptotic normal distribution to assess significance of the last lag). If no lags are significant, set $k = 0$. In the KPSS test the spectral estimation method is the Bartlett kernel and the bandwidth is be verified for different values of the lag truncation parameter. Reported in the table are the statistics for lag truncation = 4; see the text for explanation. The symbols *, **, and *** attached to the figure indicate rejection of the null of no-stationarity at the 10%, 5%, and 1% levels, respectively.

easily. Results, including the I(2) for inflation differentials between Mexico and the U.S., are very much in tandem with the ones reported in Table 1, across different values of L .

The ADF and DF-GLS tests in the upper part of Table 1 show that, except for the productivity differentials between sectors in the U.S. (*lnpme*) for the DF-GLS, the unit roots null is not rejected in levels at the 5% level. Similarly, the KPSS rejects the null of stationarity in all cases, except for the *lnpnt* in Mexico when it does so only at 10%. Thus, according to DF-GLS tests only, productivity differentials in the U.S. appear to be stationary in levels. In the lower part of Table 1 the ADF and DF-GLS tests reject the null in all cases, except for inflation differentials between Mexico and the U.S. and the DF-GLS test for *lnpme* in Korea. The latter, however, is not rejected under the KPSS test, which implies Korean *lnpme* can be reasonably inferred to be I(1). The price differentials between Mexico and the U.S. follow probably a I(2) process since ADF for *lncpi* in second differences, not reported, according to ADF is -7.89 (0) and -6.99 (0) according to DF-GLS.

In order to address the low power of unit root tests, the mixed results of some series in first differences are reinforced by complementary KPSS tests. For example, while in Korea all series except price differentials appear to be I(1) at 5%, Mexican data reject the null of stationarity for *q* and price differentials at 5%, which would suggest the two series are I(2) in Mexico according to KPSS tests. Note, however, that by both ADF and DF-GLS tests, these series are I(1). With respect to inflation differentials between Mexico and the U.S., there is consistency across the three tests. In fact, the I(2) judgment on Mexico-U.S. inflation differentials is clear from ADF, DF-GLS and KPSS tests alike.

4.2. Main Results and Discussion

Tables 2 and 3 contain Johansen cointegration tests for Korea and Mexico. The tests are conducted under the assumptions of linear deterministic trend in the data and that all series follow stochastic trends. The VAR lag length is chosen by a search on a maximal order of $k = 8$ based on the highest degree of coincidence of all statistic criteria involved (likelihood ratio, final prediction error, Akaike information criterion, Schwarz information criterion, and Hannan-Quinn information criterion). We also conduct Lagrange Multiplier tests of serial correlation under the null that there is no serial correlation. It was never possible to reject the null at 5% for the lag-length chosen by the criteria above, suggesting the VARs are devoid of serial correlation problems.

Tables 2 and 3 collect Johansen cointegration tests for Korea and Mexico, respectively. In Table 2 for Korea, there is cointegration only for the PPP model at the 5% level, although the estimated coefficient (0.30) is statistically insignificant and far from the theoretical value of 1. The other two models fail miserably for Korea: there is no cointegration and the coefficients do not match the expected values. In Table 3 for Mexico there is rejection of the null of no vectors at 5% according to the trace test for the PPP model. This implies there exists for Mexico a long-run positive relationship between price differentials and the nominal exchange rate, as postulated by PPP in Equation (9a).

Table 2. Cointegration Tests among Key Variables in Korea (1970:1-2000:4)

Model Specification	Max. Eigenv. Test	5% Critical Value	Trace Test	5% Critical Value	Null Hyp. on Coint. Vectors (C.V.)	VAR Lag Length Criteria
PPP MODEL						
$[s,\ (p-p^*)]$	15.02*	14.07	19.19*	15.41	No C.V.s	2
Vector:	4.17*	3.76	4.17*	3.76	At most 1	[LR,
$q = 0.30(p-p^*)$						FPE,
(0.20)						AIC, SC
						HQ]
PRODUCTIVITY MODEL						
$[q,(a_T-a_{NT}),(a_T^*-a_{NT}^*)]$	9.63	20.97	14.71	29.68	No C.V.s	2
Vector:	4.53	14.07	5.08	15.41	At most 1	[LR, FPE
$q = 2.53(a_T-a_{NT})$	0.56	3.76	0.56	3.76	At most 2	AIC]
(1.10)						
$-2.58(a_T^*-a_{NT}^*)$						
(1.99)						
AUGMENTED MODEL						
$[s,\ (p-p^*),(a_T-a_{NT}),(a_T^*-a_{NT}^*)]$	21.46	27.07	43.34	47.21	No C.V.s	2
Vector:	16.87	20.97	21.88	29.68	At most 1	[FPE,
$s = 1.95(a_T-a_{NT})$	4.89	14.07	5.01	15.41	At most 2	AIC,
(0.65)	0.12	3.76	0.12	3.76	At most 3	HQ]
$-2.40(a_T^*-a_{NT}^*)$						
(1.13)						
$+1.15(p-p^*)$						
(0.48)						

Notes: The variables are defined as in Table 1. Intercept and trend are included in cointegrating equation and test VAR. The data in levels have linear trends but cointegrating equation has only intercepts. The symbols ** indicates significance (rejection of the null hypothesis) at the 1% level and * indicates significance at the 5% level. Below the calculated values of the estimated coefficients by the Johansen cointegration method are marginal significance levels (*p*-values) with the exact probability. From the *k*-order VAR model, the ΔX_t and X_{t-k} are regressed on a constant and $\Delta X_{t-1},\ldots,\Delta X_{t-k+1}$. The obtained residuals R_{0t} and R_{kt} are used in the construction of the residual product matrices matrix S_{ij}. The matrix of cointegrating vectors is then estimated as the eigenvectors associated with the eigenvalues $\lambda_1 > \lambda_2 > \ldots > \lambda_r > 0$ found as the solution to $\left|\lambda S_{kk} - S_{k0}S_{00}^{-1}S_{0k}\right|$. The test statistics (for $n = 2,3,4$ variables in the system) are based on the maximal eigenvalue test and the trace test. The maximal eigenvalue test (null is r cointegration vectors against the alternative of $r+1$ cointegration vectors) is based on the statistic: $\lambda_{\max} = -T\ln(1-\lambda_{r+1})$, where T is the sample size, r is the number of cointegrating vectors, and λ_i are the eigenvalues above. The trace test (null is at most r cointegration vectors against the alternative of more than r cointegration vectors) is based on the statistic: $\lambda_{\text{trace}} = -T\sum_{i=r+1}^{P}\ln(1-\lambda_i)$. The lag-length selection criteria used were given by combination of the sequential modified likelihood ratio (LR) test, the final prediction error (FPE), and the Akaike (AIC), Schwarz (SIC) and Hannan-Quinn (HQIC) information criteria. Below the used lag-length for each specification are the criteria adopted.

Table 3. Cointegration Tests among Key Variables in Mexico (1983:1-2000:4)

Model Specification	Max. Eigenv. Test	5% Critical Value	Trace Test	5% Critical Value	Null Hyp. on Coint. Vectors (C.V.)	VAR Lag Length Criteria
PPP MODEL						
$[s, (p-p^*)]$	11.78	14.07	16.72*	15.41	No C.V.s	2
Vector:	4.94*	3.76	4.94*	3.76	At most 1	[LR, FPE, AIC, SC HQ]
$s = 1.04(p-p^*)$ (0.02)						
PRODUCTIVITY MODEL						
$[q, (a_T - a_{NT}), (a_T^* - a_{NT}^*)]$	21.04*	20.97	34.89*	29.68	No C.V.s	2
Vector:	7.93	14.07	13.85	15.41	At most 1	[LR, FPE, AIC, HQ]
$q = 28.30(a_T - a_{NT})$ (6.13) $-16.79(a_T^* - a_{NT}^*)$ (9.98)	5.92*	3.76	5.92*	3.76	At most 2	
AUGMENTED PRODUCTIVITY MODEL						
$[s, (p-p^*), (a_T - a_{NT}), (a_T^* - a_{NT}^*)]$	39.06**	27.07	89.34**	47.21	No C.V.s	8
Vector:	34.37**	20.97	50.28**	29.68	At most 1	[LR, FPE, AIC]
$s = -1.96(a_T - a_{NT})$	15.65*	14.07	15.91*	15.41	At most 2	
(1.35) $+4.12(a_T^* - a_{NT}^*)$ (1.42) $+0.76(p-p^*)$ (0.11)	0.27	3.76	0.27	3.76	At most 3	

Note: The variables are defined as in Table 1 and notes to Table 2 apply here as well.

The most interesting result is, however, the augmented productivity model in Table 3 for Mexico, representing vector (9c) above. In this case, both maximal eigenvalue and trace tests reject the null of zero cointegration at the 1% level. More importantly, the sign of the coefficients make economic sense in all cases. First, higher productivity differentials towards the tradable sector in Mexico yields an exchange rate appreciation (-1.96), although the standard error is large. Second, higher productivity differentials towards the tradable sector in the U.S. leads to a statistically significant exchange rate depreciation (+4.12). These magnitudes appear to be large but are not entirely unheard of. A recent study by Alquist and Chinn (2002), for example, reports robust elasticities of the Euro-USD real exchange rate with respect to log productivity differentials between 4 and 5. They recall that in most productivity-based models, productivity increases yield appreciations of a magnitude comparable to the share of nontradables in the aggregate basket. In their own words, "this means that the coefficient on productivity should be bounded in absolute value between zero and one…, which makes it difficult to appeal to measurement error in explaining this finding. Even assuming that both the relative price variable and the broad productivity indices mismeasure the relevant tradable/nontradable productivity differential, the observed elasticity is still more than four times the expected magnitude." (Alquist and Chinn (2002, pp. 5-6))[2] Finally, price differentials move positively with the nominal Mexican Peso exchange rate: a statistically significant +0.76 coefficient, away from 1.0, but still positive and significant.

Given the evidence in Table 1 that uncovered a probable I(2) for price differentials between Mexico and the U.S. (*lncpi*), we perform next Stock and Watson (1993) dynamic ordinary least squares (DOLS) estimations in Table 4. All model specifications are listed at the top of Table 4 and the lagged and lead terms on $(p-p^*)$ are differenced twice to achieve stationarity under Mexican data.[3] For each country, we estimate two sets of equations with 2 leads and lags for all terms as suggested by Stock and Watson (1993) and also eliminate the insignificant differenced terms based on a 10% or less confidence level.

The "PPP only" model in Table 4 supports a close to 1.0 estimate of β_1 in Korea and in Mexico. In both cases, the coefficient is statistically significant and in agreement with theory. Higher domestic price levels with respect to the U.S. require higher (peso or won) spot rates. The standard productivity model implies statistically significant 1.65 or 1.50 levels for the domestic productivity differential in Korea and much higher 5.89 or 7.91 β_1 coefficients in Mexico. The positive level found for β_1 does not match one's priors since higher productivity of tradables implies a depreciation of the real exchange rate, in violation of Equation (7). The U.S. productivity level is found positive and statistically significant only for Mexico in the specification with all leads and lags (11.32).

[2] In Strauss (1996), Equation (8) is not estimated but Equation (7) provides similar larger than expected coefficient values. For instance, the coefficient on domestic productivity differentials varies from -1.05 in Belgium to -10.53 in France. Similarly, the coefficient on foreign (Germany) productivity differentials varies from 0.05 in Belgium to 13.97 in France, including a contrary to what expected coefficient of -8.72 for Finland. These values are certainly much larger than the original theoretical idea of measuring the shares α and α^*, necessarily between 0 and 1. These findings imply that the cointegration-based coefficient contains more than the share of each sector in total domestic price level, which casts doubt on the strict empirical fitness of this productivity model.

[3] Recall that in the demand for money estimations in Stock and Watson (1993), the net national product price deflator (p , in logarithms) is judged to be either I(1) or I(2). This motivates their specification of p as I(2) and the lower triangular representation for an I(d) process satisfying a set of conditions supporting the DOLS estimations. The I(2) feature of prices is found in other economies as well. See, for example, Muscatelli and Spinelli (2000) for Italian money demand in the very long run.

Table 4. Stock and Watson (1993) DOLS Cointegration Tests of the Models

PPP only: Korea: $s_t = \beta_0 + \beta_1(p-p^*)_t + d_p(L)\Delta(p-p^*)_t + \varepsilon_t$

Mexico: $s_t = \beta_0 + \beta_1(p-p^*)_t + d_p(L)\Delta^2(p-p^*)_t + \varepsilon_t$

Standard Productivity:

$$q_t = \beta_0 + \beta_1(a_T - a_{NT})_t + d_a(L)\Delta(a_T - a_{NT})_t + \beta_2(a_T^* - a_{NT}^*)_t + d_{a*}(L)\Delta(a_T^* - a_{NT}^*)_t + \varepsilon_t$$

Augmented:

Korea: $s_t = \beta_0 + \beta_1(a_T - a_{NT})_t + d_a(L)\Delta(a_T - a_{NT})_t + \beta_2(a_T^* - a_{NT}^*)_t + d_{a*}(L)\Delta(a_T^* - a_{NT}^*)_t$

$+ \beta_3(p-p^*)_t + d_p(L)\Delta(p-p^*)_t + \varepsilon_t$

Mexico: $s_t = \beta_0 + \beta_1(a_T - a_{NT})_t + d_a(L)\Delta(a_T - a_{NT})_t$

$+ \beta_2(a_T^* - a_{NT}^*)_t + d_{a*}(L)\Delta(a_T^* - a_{NT}^*)_t + \beta_3(p-p^*)_t + d_p(L)\Delta^2(p-p^*)_t + \varepsilon_t$

Estimated Model	Korea (all leads and lags)	Korea (only significant leads and lags)	Mexico (all leads and lags)	Mexico (only significant leads and lags)
PPP Only				
β_0	6.83^{***}	6.81^{***}	1.65^{***}	1.65^{***}
	(0.04)	(0.04)	(0.03)	(0.03)
β_1	0.94^{***}	0.98^{***}	0.94^{***}	0.94^{***}
	(0.07)	(0.06)	(0.02)	(0.02)
T (sample size)	119	122	66	70
Adj. R^2	0.873	0.883	0.985	0.989
Standard Prod.				
β_0	6.52^{***}	6.58^{***}	5.63^{***}	5.95^{***}
	(0.21)	(0.12)	(0.62)	(0.55)
β_1	1.65^{***}	1.50^{***}	5.89^{*}	7.91^{***}
	(0.39)	(0.21)	(3.19)	(2.94)
β_2	0.08	0.26	11.32^{**}	7.60
	(0.71)	(0.37)	(5.51)	(4.77)
T (sample size)	119	121	67	68
Adj. R^2	0.868	0.868	0.903	0.905
Augmented Prod.				
β_0	6.55^{***}	6.56^{***}	1.14^{***}	1.11^{***}
	(0.08)	(0.08)	(0.16)	(0.15)
β_1	0.79^{***}	0.75^{***}	-2.16^{***}	-2.03^{***}
	(0.18)	(0.14)	(0.37)	(0.35)
β_2	-0.75^{***}	-0.70^{***}	2.48^{***}	2.06^{***}
	(0.33)	(0.30)	(0.56)	(0.59)
β_3	0.61^{***}	0.64^{***}	1.08^{***}	1.09^{***}
	(0.11)	(0.09)	(0.06)	(0.05)
T (sample size)	119	121	66	67
Adj. R^2	0.910	0.915	0.992	0.992

Notes: The method of estimation is the DOLS developed by Stock and Watson (1993). The models are: the PPP only (s as function of $p-p^*$), the standard productivity model (the real exchange rate explained by sector productivity differentials in the two economies) and the augmented productivity model (the exchange rate explained by sector productivity and inflation differentials in the two economies). The estimates include 2 leads and 2 lags of the first differences in the regressions. In the equations above, $d(L)$ represents the polynomial in terms of the lag operator. Below the reported coefficients are the standard errors computed by Newey-West correction for heteroskedascity and autocorrelation.

This matches Equation (7) since a higher U.S. productivity level would contribute to a stronger dollar and a lower peso, which would imply a positive correlation with the real exchange rate. However, the results on β_1 seriously cast doubt on the adequacy of the standard productivity model for both countries.

Observe next the evidence from the augmented productivity model at the lower part of Table 4. Consider the results for Mexico first at the right side of the table. The negative β_1 coefficient slightly over -2 suggests that higher domestic productivity of tradables implies an appreciation of the real exchange rate as formulated by Equation (7). Also, the β_2 coefficient of over 2 implies that the U.S. productivity level affects positively the nominal exchange rate in Mexico according to both specifications with all leads and lags and the more parsimonious one. Coupled with the results for β_1, this suggests the Stock and Watson methodology is unable to bring the coefficient value to the theoretical share of non-tradables in the price index. For the Mexican peso, however, the values associated with domestic productivity differentials remain very close across models: -1.96 by the Johansen method in Table 3 and varying between -2.03 and -2.16 by the Stock and Watson procedure in Table 4. These values imply that each percentage point in productivity differentials results in a 2% appreciation of the peso.

The fact that coefficient values remain larger than 1 in absolute value matches the empirical finding uncovered by Maeso-Fernández *et al.* (2001) and Alquist and Chinn (2002) under productivity-based models of the euro. Finally, the β_3 coefficient is very close to the theoretical value of one in Mexico, implying that rises in the Mexican inflation with respect to U.S. inflation are accompanied by depreciations of the Mexican Peso exchange rate. For Korea, however, the augmented productivity model does not fit so well. Indeed, the only theoretical "correct" coefficient is the one for inflation differentials (β_3), varying between 0.61 and 0.64. The other two are statistically significant but with their signs contrary to theoretical predictions of the productivity-based models discussed above. Alquist and Chinn (2002) mention that competing (neoclassical or Ricardian) models suggest different relationships. Increases in productivity, for example, reduce the relative price of home goods and lead to depreciations of the currency. This has been operative for Korea across the two methodologies of cointegration. Tables 2 and 4 report +1.95 coefficient on relative domestic productivity by Johansen and +0.75 or +0.79 by Stock and Watson and -2.40 coefficient on relative U.S. productivity by Johansen and -0.70 or -0.75 by Stock and Watson.

We consider three explanations for the failure of the augmented productivity model in Korea. First and more fundamentally, coefficients with contrary signs obtained in Korea may indicate competing models (neoclassical or Ricardian) are more appropriate to capture the relationship between productivity and exchange rates. Looking at the trend of the explanatory variables in the augmented productivity model, as can be seen in Figure 1 under Korean data, the relative traded goods productivity gap (*lnprodkr*) is growing overall but suffers a slowdown in the mid to late 80s. This contrasts to the monotonically increasing traded goods productivity gap in Mexico shown in Figure 2.

Since higher domestic traded goods productivity gap implies an appreciation of the currency, the fact that the series fails to grow uniformly may contribute to a smaller coefficient in the Korean case. Or, worse still for the set of models above, the empirical evidence in this paper may be suggestive of competing productivity models.

Second, the benchmark adopted is the U.S. economy, which at first glance appears much more important in Mexico than in Korea.[4] However, the U.S. is the largest South Korean trade partner today and South Korea is the United States' 7th largest trading partner, 6th largest export market and 4th largest market for agricultural goods. (http://www.kita.org). This suggests that choosing a different benchmark than the USD does not sound particularly convincing. Although skeptic of such route, we estimate once more the models above under Japanese and Korean annual data, due to data availability. Of course, the estimates under annual data suffer from low power of the cointegration tests. In any case, the results were never satisfactory for the won/yen nominal and real exchange rates as function of relative sector productivities in Japan and Korea.[5]

The third possibility is the institutional framework associated with the exchange rate regime. Inspection of Figures 1 and 2 indicates that nominal and real exchange rates move closely together in the two countries. In other words, the source of the fluctuation in q is solely the randomness in the spot rate. A co-movement between nominal and real exchange rates can only happen when inflation differentials are relatively stable, which occurs only in the more recent past. The Mexican Peso followed various pegged exchange rate regimes during the eighties, until December of 1994 when the financial crisis erupted. Similarly, the Korean Won was effectively pegged to the USD until March 1990, when the authorities adopted the so-called market average rate (MAR) system, in which supply and demand determined exchange rates subject to a daily price level (Takagi (1999)). In 1997, the Won started to float in the wake of Asian currency crisis turmoil. The implication of this standpoint is that any model of the exchange rate is better built with financial (monetary aggregates, interest rates, etc.) rather than real (productivities) series, along the lines of Chinn (1998).

[4] Canzoneri *et al*. (1999) argue the productivity-based model is much more successful when the German mark (DEM) is used instead of the USD. Such benchmark argument appears indeed in other studies. Due to abnormally high fluctuations in the USD during the 80s, Strauss (1996) estimates the productivity model under the DEM and the French Franc as benchmarks with more supportive findings.

[5] Results of unit roots, Johansen, and Stock and Watson cointegration tests for the won/yen estimations are available upon request, as well as a new data description. There was considerable more variation in estimates than the estimates above under quarterly data. Results were very sensitive to lag-length and, especially, to elimination of insignificant terms in the Stock and Watson procedure.

5. CONCLUDING REMARKS

This paper finds that the traditional PPP model performs well for the Mexican peso/ USD real exchange rate under quarterly data from 1983 to 2000. Cointegration is found under two methodologies and the coefficient of the nominal exchange rate with respect to price differentials in Mexico varies narrowly from 0.94 to 1.04 across methods, very close to the unit theoretical value. The standard productivity model, however, linking the real exchange rate to domestic and foreign productivity differentials between traded and non-traded sectors is strongly rejected for both countries, in contrast to Strauss (1996) and Tille *et al*. (2001), who employ annual data for 30 years in industrial countries with some support for the theory.

The augmented productivity model, however, well predicts the Mexican peso against the USD: as Mexican traded goods productivity rises, the nominal exchange rate appreciates, while as U.S. traded goods productivity rises, the nominal exchange rate depreciates, and the effect of price differentials on the exchange rate is close to 1.0. Similar to Maeso-Fernandez *et al*. (2001) and Alquist and Chinn (2002) under productivity-based models of the euro, however, the values of the coefficients are well beyond the theoretical expected values between 0 and 1 associated with the share of each type of good. For the Mexican peso, the values on domestic productivity differentials remain very close across models: -1.96 by the Johansen method and between -2.03 and -2.16 by the Stock and Watson procedure. These values imply that each percentage point in productivity differentials results in a 2% appreciation of the peso.

The results of the productivity-based model are less supportive under Korean data from 1970 to 2000, where the coefficients are more consistent with implications from competing models of productivity. We leave a comparative investigation between the set of models discussed in this paper and competing productivity models to further research.

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Manuscript received April, 2003; final revision received March, 2004.