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14 Testing for the Fundamental Determinants of the Long-Run Real Exchange Rate: The Case of Taiwan

Hsiu-Ling Wu

14.1 Introduction

The real exchange rate between two countries' currencies has been recognized as a key measure of the prices of foreign goods relative to domestic goods in those countries. Since the real exchange rate reveals the relative competitiveness of exported goods from the two economies, it is desirable to characterize the behavior of the real exchange rate and test for its fundamental determinants.

The behavior of the real exchange rate is intimately related to the behavior of deviations from purchasing power parity (PPP). According to PPP theory, nominal exchange rates adjust to offset changes in relative prices, so the real exchange rate should remain at a constant value. However, there is widespread agreement that substantial deviations from PPP have occurred since the abandonment of the Bretton Woods system.[1] That is, there is no equilibrium value to which the real exchange rate tends to return. In empirical tests, many authors indeed cannot reject the hypothesis that real exchange rates follow a random walk process (see, e.g., Frenkel 1981; Hakkio 1986; Mark 1990). Thus changes in the real exchange rate are considered permanent. Some kinds of real disturbances are believed to upset the relationship between the nominal exchange

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1. There are two versions of PPP theory, absolute PPP and relative PPP. Absolute PPP theory, which relies on the law of one price, states that the general level of prices, when converted to a common currency, will be the same in every country ($P = EP^*$). Absolute PPP holds only if two price levels are computed in the same way as weighted tradable prices in a competitive world market with no transportation costs or trade barriers. Therefore, absolute PPP can hardly be expected to hold in the real world. Relative PPP theory says that the rate of change in the nominal exchange rate is equal to the domestic inflation rate minus the foreign inflation rate. The validity of relative PPP is often tested by implementing the regression analysis of $\ln P = \ln E + \ln P^* + e$.

rate and relative price levels as postulated by PPP so that the behavior of real exchange rates is found to be inconsistent with PPP.

To assess the fundamental factors determining the behavior of the real exchange rate, a number of studies have considered productivity differentials between the nontraded and traded sectors of economies as a prime cause of permanent changes in the real exchange rate. According to Balassa (1964), if productivity in the domestic traded goods sector grows more rapidly than productivity in the nontraded goods sector, under the assumption of equalization in wages across sectors, the relative price between traded and nontraded goods has to fall. Since the prices of traded goods are equalized between countries through international arbitrage, the general price level will rise at home. It follows that the real exchange rate will appreciate. Hsieh's (1982) work uses time-series data for Germany and Japan versus their respective major trading partners to study the relationship between movements in real exchange rates and productivity growth differentials in the traded and nontraded sectors. His study has provided strong evidence supporting the idea that productivity differentials are useful in explaining the movements in real exchange rates.

Marston (1987) investigated the effects of productivity growth differentials between the United States and Japan on alternative real exchange rates between the yen and dollar. Since real exchange rates based on alternative price series can diverge when there are shifts in supply factors within a country, Marston considered different expressions of real exchange rates to evaluate the relative competitiveness of the two economies. For instance, from 1973 to 1983 the yen appreciated in terms of the GDP deflator by 0.3 percent, while the real exchange rate expressed in terms of the GDP deflator for traded goods alone depreciated 26.7 percent. This result suggests that real exchange rates based on different price indexes may lead to very different conclusions. Thus it is desirable to find out what can account for the divergence between two real exchange rate series. According to Marston, the differential movement between any two real exchange rates results from relative unit labor cost changes in traded sectors at home and in the foreign country and unit labor cost changes in traded sectors of each country relative to the nontraded sectors. Since sectoral wage trends are similar in the United States and Japan, it is relative productivity movements in traded and nontraded sectors that explain the difference of movements in real exchange rates.

In the real world, it is observed that during the 1973–1983 period, productivity growth in the Japanese traded sector was 73.2 percent greater than in the nontraded sector, and productivity in the U.S. traded sector grew only 13.2 percent faster than in its nontraded sector. The markedly higher productivity growth differential together with the lack of any substantial decline in nominal wages in the United States, therefore, reduced the relative competitiveness of U.S. exports.

The empirical purpose of this article is to investigate the factors that determine long-run movements of the real exchange rate of the New Taiwan (NT) dollar against the U.S. dollar. Recent developments in time-series analysis have provided new ways of analyzing the long-run relationships for our purpose. In particular, the theory of cointegration provides a means of establishing whether a long-run relationship exists between economic variables. Since testing for cointegration among economic variables seems to have become a standard method of assessing the empirical support for the equilibrium of economic behavior, we wish to test the behavior of the real exchange rate by applying the principle of cointegration. This paper is not limited to a test of the theory of PPP. It will also test for the role of the fundamental factor—productivity—that has been identified in several papers as determining movements in real exchange rates.

The organization of the article is as follows. In section 14.2 I give an introduction to the evolution of exchange rate management in Taiwan. In section 14.3 the movements of real exchange rates, nominal exchange rates, and relative price levels are briefly discussed. In section 14.4 analysis using cointegration approaches is discussed. Section 14.5 tests for the long-run properties of real exchange rate movements. In section 14.6 I evaluate the effects of changes in nominal exchange rates and in foreign and domestic price levels on the real exchange rate. In section 14.7 I look into the relationship between real exchange rate change and relative productivity growth of traded and nontraded sectors. Section 14.8 summarizes the overall findings of the paper.

14.2 The Evolution of Exchange Rate Management in Taiwan

Before January 1979, the NT dollar was tied to the U.S. dollar. This was primarily because the United States was Taiwan's most important trading partner and most Taiwanese international contracts were denominated in U.S. dollars. The pegging system helped reduce exporters' uncertainties in international trade. However, the system had some drawbacks. It was commonly recognized that the domestic economy would become more vulnerable to external disturbances. For instance, Taiwanese exports would be less competitive in the U.S. market as the U.S. dollar soared against other currencies.

With the promulgation of the revised Foreign Exchange Regulation, a foreign exchange market was established on 1 February 1979, and a managed floating rate system was introduced in Taiwan. When the new exchange rate system was adopted, the exchange rate of the NT dollar against the U.S. dollar was at first fixed by an ad hoc committee comprising five representatives from five appointed banks[2] and one representative from the central bank. From

2. They are the Bank of Taiwan, the International Commercial Bank of China, the First Commercial Bank of Taiwan, the Chang-Hwa Commercial Bank of Taiwan, and the Hwa-nan Commercial Bank.

March 1980, the central bank delegated the other members of the committee to fix the daily spot and forward exchange rates. The ad hoc committee took into account the demand and supply of foreign exchange as well as the real effective exchange rate index of the NT dollar when fixing the spot rate of the NT dollar against the U.S. dollar.[3]

After trial and error, the mechanism for exchange rate determination evolved in 1982 into a form that was based on the weighted average rate of interbank transactions in U.S. dollars on the previous business day.[4] Daily fluctuations of the interbank rate have only been allowed to float within a 2.25 percent range from the weighted average rates on all interbank currency exchange transactions, which were established daily by the five representatives from the ad hoc committee. To maintain an orderly foreign exchange market, the central bank also intervened on many occasions by buying and selling the U.S. dollar in the interbank market.

As was widely noticed, because of the huge trade surplus and the considerable influx of private short-term capital, the supply of foreign exchange far exceeded the demand in Taiwan during the mid-1980s. As a result, the exchange rate of the NT dollar against the U.S. dollar appreciated steadily from 1986 to 1989. The NT dollar appreciated against the U.S. dollar by 12.25 percent over 1986, 24.34 percent over 1987, 1.35 percent over 1988, and 7.13 percent over 1989. During this period, the central bank's intervention in the foreign exchange rate involved direct buying and selling of foreign exchange in the interbank market to stabilize wide fluctuations in the value of the NT dollar that otherwise have would occurred, since officials at the central bank believe that the exchange rate should be adjusted in a smooth way rather than in substantial one-shot appreciations. This intervention, however, has two additional effects. First, it raises the level of foreign exchange reserves. Second, it generates an expansionary effect on the local money supply. Hence, the central bank has introduced a series of measures to liberalize foreign exchange controls since 1986 to address the external disequilibrium. It has also applied other policies, such as increasing reserve requirements for savings deposits and issuing bonds and treasury bills to banks to limit credit expansion.

In addition to liberalizing Taiwanese capital controls, the central bank also changed the foreign exchange rate trading system in 1989 to accelerate economic liberalization and internationalization in Taiwan. The bank abolished the former system, which used the weighted average rate of interbank transac-

3. E.g., the devaluation of the NT dollar against the U.S. dollar by 4.63 percent in August 1981 was to make up for the loss of competitiveness resulting from real effective overvaluation since the U.S. dollar was strengthening against other currencies.

4. Taiwan has mechanisms for managing exchange rates in both the interbank and customer-bank foreign exchange markets. The interbank market consists of foreign exchange transactions between banks. Customer-bank transactions refer to individuals changing currency with a designated foreign exchange bank. It is the interbank market that has played a pivotal role in setting exchange rates.

tions as the central rate on the next business day and had set limits on daily fluctuations. According to the central bank, after some additional modifications are made, the structure of the foreign exchange market in Taiwan will be more complete and concrete, since its operating methods will be similar to those prevailing in developed countries. This should make the exchange rate for the NT dollar more flexible, and it will reflect its actual value in the market.

14.3 The Movements of the Real Exchange Rate

Exchange rate changes can be measured in nominal or real terms. A measure in real terms against one currency provides a better measure of relative competitiveness than do measures in nominal terms. Consider the real exchange rate (R) defined in terms of nominal exchange rate (E) adjusted for relative price levels (P^*/P), that is, $R = EP^*/P$. In our case, the nominal exchange rate is defined as the NT dollar price of U.S.\$1, so that an increase in E indicates a depreciation of the NT dollar; the asterisk denotes the foreign (U.S.) economy. A rise in real exchange rate (i.e., a real depreciation of the NT dollar) corresponds to a fall in the purchasing power of domestic currency for foreign products. This change in relative purchasing power occurs because the NT dollar prices of U.S. products rise relative to those of Taiwanese products.

Figure 14.1 shows the fluctuations of the nominal exchange rate, relative price level, and real exchange rate between 1985 and 1995. The nominal exchange rate appreciated by 34.35 percent from 1985 to 1989. This was matched by a 22.16 percent real appreciation during the same period. Thus it seems that both nominal exchange rate appreciation and inflation differentials between domestic and foreign countries were responsible for changes in real exchange rates, though the real exchange rate movements were mainly caused by the nominal appreciation of the NT dollar during the 1985–89 period. The upward movements of the relative price level offset some effects of the nominal appreciation of the NT dollar against the U.S. dollar, so that the magnitude of real appreciation was smaller than that of the nominal exchange rates.

As shown in figure 14.1, the nominal exchange rate started to fluctuate in a more stable range between NT\$27.5/U.S.\$1 and NT\$25.5/U.S.\$1 since 1989. During the same period, fluctuations of the real exchange rate were also not as volatile as in the 1985–89 period. However, during the period 1989–95, it appeared that real exchange rate movements were dominated more by inflation differentials between Taiwan and the United States than by nominal exchange rate changes. Hence, in the following sections I will evaluate aspects of real exchange rate behavior by analyzing (1) the extent to which real exchange rates revert, in the long run, to PPP, (2) the persistent effect of a nominal exchange rate and domestic and foreign price level adjustment on the real exchange rate, and (3) the equilibrium relationship between the real exchange rate and differentials of productivity growth between traded and nontraded goods.

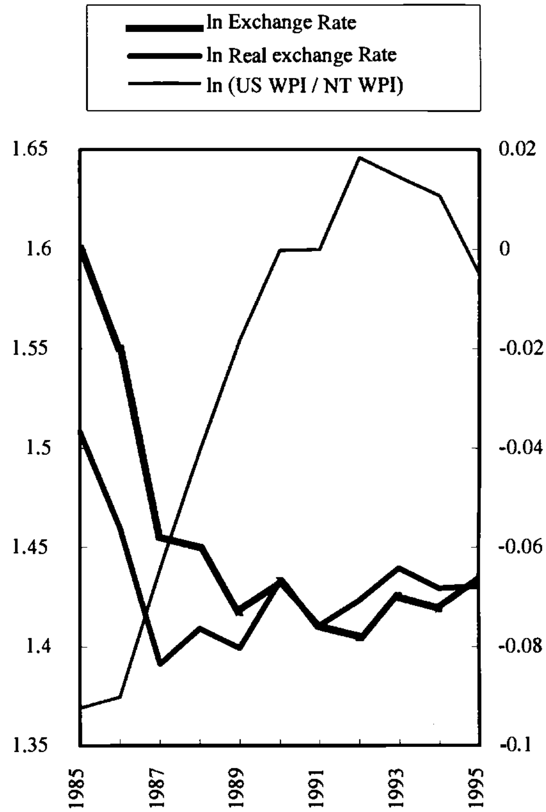

Fig. 14.1 Nominal exchange rate, real exchange rate, and relative price level between U.S. and NT dollars

14.4 Vector Autoregressive Modeling and the Cointegration Approach

This section discusses the cointegration approach, which provides not only an estimation methodology but also explicit procedures for testing a long-run relationship among variables that is suggested by economic theory.

According to the Granger representation theorem, if a $p \times 1$ vector, X_t, generated by $(1 - L)X_t = d + c(L)e_t$, is cointegrated, then there exists a vector autoregression (VAR), an error correction, as well as a moving average representation of X_t (see Engle and Granger 1987). A set of variables, X_t, that is cointegrated indicates the existence of long-run equilibrium relationships among economic variables. That is, though each series may be nonstationary, there may exist stationary linear combinations of the variables. The basic idea is that individual economic time-series variables wander considerably, but certain linear combinations of the series do not move too far apart from each other. In economic terms, there is a long-run relationship among the variables.

The most common test for cointegration is the two-step procedure of Engle and Granger (1987), which performs the tests in a univariate setup. The first step is to fit the cointegrating regression, which is the ordinary least squares estimation of the static model. Second, a unit root test is conducted on the estimated residuals. To test for cointegration is just to test for the presence of a unit root in the residuals of the cointegrating regression. If the null of a unit root is rejected, then the null of no cointegration is also rejected. However, the long-run parameter of the cointegrating vector estimated from this approach can be severely biased in finite samples. An improved procedure for testing for cointegration, allowing for more than one cointegration vector, is suggested in Johansen (1988) and Johansen and Juselius (1990).

Following Johansen and Juselius (1990), let the p variables under scrutiny follow a vector autoregression of order k (VAR(k)) as below:

$$X_t = \mu + \Pi_1 X_{t-1} + \cdots + \Pi_k X_{t-k} + \varepsilon_t, \qquad t = 1, \ldots, T,$$

where $\varepsilon_1, \ldots, \varepsilon_t$ are innovations of this process and are assumed to be drawn from a p-dimensional i.i.d. Gaussian distribution with covariance Γ and $X_{-k+1}, \ldots, X_0$ are fixed. Let Δ represent the first-difference operator. The equation can be reparameterized into the equivalent form presented below:

$$\Delta X_t = \mu + \Pi X_{t-k} + \sum_{i=1}^{k-1} I_i \Delta X_{t-i} + \varepsilon_t, \qquad t = 1, 2, 3, \ldots,$$

where

$$I_t = -I + \sum_{j=1}^{i} \Pi_j, \qquad i = 1, \ldots, k-1, \quad \Pi = I + \sum_{j=1}^{k} \Pi_j.$$

The coefficient matrix Π contains information about the long-run relationship among the variables. Since ε_t is stationary, the number of ranks for matrix Π determines how many linear combinations of X_t are stationary. If $0 <$ rank $(\Pi) = r < p$, there exist r cointegrating vectors that make the linear combinations of X_t stationary. In that case, Π can be factored as $\alpha\beta'$, with α and β being matrices. β is a cointegrating vector that has the property that $\beta' X_t$ is stationary even though X_t itself is nonstationary; α then contains the adjustment parameters.

Based on the unrestricted estimation that is parameterized in terms of level and differences, Johansen (1988) proposed likelihood ratio statistics for testing the number of cointegrating vectors. First, we must solve for the eigenvalues of

$$|\lambda S_{kk} - S_{k0} S_{00}^{-1} S_{0k}| = 0,$$

where S_{00} is the moment matrix of the residuals from the ordinary least squares regression of ΔX_t on $\Delta X_{t-1}, \ldots, \Delta X_{t-k+1}$; S_{kk} is the residual moment matrix from the ordinary least squares regression of ΔX_{t-k} on $\Delta X_{t-1}, \ldots, \Delta X_{t-k+1}$; and S_{0k} is the cross-product moment matrix. The cointegrating vector, β, is solved out as the eigenvectors associated with the r largest statistically significant eigenvalues are derived using two test statistics, "maximum eigenvalue statistics" and "trace statistics." The first statistic tests the hypothesis that there are $r = s$ cointegrating vectors against the alternative of $r = s + 1$ by calculating the maximum likelihood test statistics as $-T\ln(1 - \lambda_{s+1})$, where T is the sample size and λ_{s+1} is an estimated eigenvalue. The second statistic tests the hypothesis that there exist at most r cointegrating vectors. It is performed by calculating so-called trace statistics:

$$-T \sum_{i=r+1}^{p} \ln(1 - \lambda_i),$$

where $\lambda_{r+1}, \ldots, \lambda_p$ are the estimated $p - r$ smallest eigenvalues. Given the number of cointegrating relations, with or without a linear trend, the data can also be analyzed by another reduced rank regression by calculating the test statistics

$$-T \sum_{i=r+1}^{p} \ln[(1 - \lambda_i^*)/(1 - \lambda_i)],$$

where λ_i^* are eigenvalues obtained from cointegration analysis assuming there is no linear trend.

14.5 Real Exchange Rate in the Long Run

In this section, I investigate the behavior of the real exchange rate with cointegration methods to see whether its long-run movement is consistent with the implications of PPP theory. The relative PPP theory asserts that the rate of change in the nominal exchange rate is equal to the domestic inflation rate minus the foreign inflation rate. This implies that when the nominal exchange rate goes up or down, relative price levels will adjust continuously in order to keep the real exchange rate close to its long-run equilibrium level. The equation for the relative PPP theory may be rearranged to produce an expression for the change in the real exchange rate, so that the real exchange rate change should equal zero.

To investigate whether there are deviations of the real exchange rate away from its equilibrium value, I test for cointegration relations among changes in nominal exchange rates and domestic and foreign price levels without imposing any proportionality and symmetry restrictions, instead of checking the stochastic process of the real exchange rate series by a unit root test.[5] I do this because of the suggestion of Cheung and Lai (1993) that measurement errors in price variables would cause violations of the symmetry restrictions of the

5. If the real exchange rate series is stationary, i.e., the series contains no unit root, then it tends to fluctuate around the mean in the long run. Nonstationary series, however, wander widely and rarely return to an earlier value. Thus real exchange rates change, and this change quantifies deviations from PPP.

absolute PPP theory and thus cause us to erroneously accept the hypothesis of a nonstationary real exchange rate.[6]

The estimating model for such a version may be empirically formulated as:

$$\ln E = a_0 + a_1 \ln P + a_2 \ln P^* + u,$$

where E denotes the bilateral nominal exchange rate, P is the domestic price level, P^* stands for the foreign price level, and u is the error term. Testing for a cointegrated relationship among a set of variables is done in two steps. The first step is to verify the order of integration of the variables. Second, cointegration tests are conducted on variables with compatible properties. The stochastic properties of variables can be investigated by applying the augmented Dickey-Fuller (ADF) test. The hypothesis that the variable X_t is an $I(1)$ series is tested by conducting a regression on the following equation:

$$\Delta X_t = \mu + \beta t + \alpha X_{t-1} + \sum_{i=1}^{p} K_i \Delta X_{t-i} + \varepsilon_t,$$

where X_t stands for variables appearing in the equation; p is the number of lags chosen to ensure that the estimated residuals, ε, are approximately white noise; μ is the constant term; and t is a time trend (see Dickey and Fuller 1979; Dickey 1981). If we cannot reject the hypothesis that X_t is a unit root process, then the unit root test is applied to ΔX_t. X_t is an $I(1)$ series only when ΔX_t is not a unit root process.

Monthly observations from January 1981 through September 1995 were used for the empirical study. The nominal exchange rate series, which are monthly average rates, are collected from *Financial Statistics Monthly (Taiwan District)* published by the Central Bank of Taiwan. The relevant price indexes for Taiwan are also from *Financial Statistics Monthly*, whereas the U.S. data are from the *International Financial Statistics* tape from the International Monetary Fund.

The results of the unit root test are reported in table 14.1. The autoregressive lag lengths are chosen to be shortest for the residuals from the regression, which the Box-Ljung Q-statistic suggests are white noise. As shown in table 14.1, the null hypothesis of a nonstationary exchange rate cannot be rejected for the log levels of all the variables. The unit root tests of the first difference of the logarithms of the variables lead us to reject the unit root null hypothesis at the 95 percent significance level, since the ADF statistics are significantly negative. In summary, the tests indicate that the variables of nominal exchange

6. Since observed price series are imperfect proxies for theoretical price variables, some measurement errors exist. These measurement errors can be associated with international differences in consumption patterns, variations in product quality, and differences between listed and transaction prices. If symmetry and proportionality conditions are not consistent with the data, the imposition of these conditions can bias PPP tests on real exchange rates toward finding nonstationarity. In such a case, a finding of a nonstationary real exchange rate can indicate a violation of the symmetry or proportionality restrictions and still be consistent with PPP theory.

Table 14.1 Unit Root Tests for Nominal Exchange Rate and Price Levels

	Variables				
	ln *E*	ln WPI	ln WPI*	ln CPI	ln CPI*
Level	−0.93941	−1.6104	−0.00234	1.4516	−1.6834
First difference	−3.747	−4.0775	−5.937	−7.0238	−5.1668

Note: The critical value at the 95 percent significance level is −3.45 for $N = 100$ (Fuller 1976, 373).

Table 14.2 Johansen Maximum Likelihood Procedure: Cointegration Likelihood Ratio Test Based on Maximal Eigenvalue of the Stochastic Matrix

Null	Alternative	Statistic	95% Critical Value
		(ln *E*, WPI, WPI*)	
$r = 0$	$r = 1$	18.2347	21.0740
$r \leq 1$	$r = 2$	6.4360	14.9000
$r \leq 2$	$r = 3$	4.2808	8.1760
		(ln *E*, CPI, CPI*)	
$r = 0$	$r = 1$	18.5323	21.0740
$r \leq 1$	$r = 2$	11.4005	14.9000
$r \leq 2$	$r = 3$	5.4206	8.1760

rates and domestic and foreign price levels are compatibly integrated of order one and these variables are suitable for the cointegration test.

To test for the cointegration relationship, the Johansen approach to the cointegration test was performed in the VAR framework. In order to avoid any bias of the regression result by measurement errors, the cointegrating regression was considered without imposition of symmetry and proportionality restrictions. Table 14.2 reports the values of the Johansen test statistics, indicating that changes in nominal bilateral exchange rates are not cointegrated with those in domestic and foreign price levels, when either the WPI or CPI is used. The results appear to suggest that the simple notion of the PPP relationship did not hold for the real exchange rate between the Taiwanese and U.S. currencies during the period under review. This implies that the nominal bilateral exchange rate for the NT dollar vis-à-vis the U.S. dollar and the corresponding price levels drifted away from each other following shocks to the Taiwanese economy. More generally, this indicates that movements in real exchange rates can be regarded as permanent and the real exchange rate should not be expected to return to the equilibrium PPP value.

14.6 Impulse Response Analysis

Our inability to reject the null hypothesis of a cointegration relationship between the nominal exchange rate and foreign and domestic price levels implies that shocks to the real exchange rate are so persistent that it does not return to the long-run value, as PPP theory predicts. Because real exchange rates are constructed by nominal exchange rates and relative price levels, the variability in real exchange rates can be dominated by either nominal exchange rates or relative price level changes. In this section, we investigate the extent to which the nominal exchange rate and foreign and domestic price level changes affect the real exchange rate through an analysis of their impulse response functions.

For this purpose, we estimated an unrestricted VAR consisting of the first difference in the logarithms of the nominal exchange rate and domestic and foreign price levels:

$$A(L)X_t = \mu_t,$$

where

$$X_t = (\Delta P_t,\ \Delta E_t,\ \Delta P_t^*),\quad A(L) = \sum_{j=0}^{k} A_j L^j,\quad A_0 = I.$$

Akaike's information criterion was employed to select the lag length of the VAR system. Inverting $A(L)$, we get the moving average representation $X_t = A(L)^{-1}\mu_t$. To evaluate the dynamic response of the variables in X_t to an innovation in ΔP_t, ΔE_t, and ΔP_t^*, μ_t is orthogonalized by means of a Choleski factorization of Ω. Let $\varepsilon_t = B\mu_t$, with B chosen to be a lower triangular matrix such that $B\Omega B' = I$. I is a diagonal matrix. Thus we can write $X_t = C(L)\varepsilon_t$, where

$$C(L) = A(L)^{-1}B(L)^{-1} = \begin{bmatrix} C_{11}(L) & C_{12}(L) & C_{13}(L) \\ C_{21}(L) & C_{22}(L) & C_{23}(L) \\ C_{31}(L) & C_{32}(L) & C_{33}(L) \end{bmatrix}.$$

The changes in P, E, and P^* responding to a unit shock to P are given by $C_{11}(L)$, $C_{21}(L)$, and $C_{31}(L)$, respectively. Similarly, the changes in P, E, and P^* responding to innovations in E and P^* are presented by $C_{12}(L)$, $C_{22}(L)$, and $C_{32}(L)$ and $C_{13}(L)$, $C_{23}(L)$, and $C_{33}(L)$. Therefore, the implied changes in R following shocks to P, E, and P^* are $(-C_{11} + C_{21} + C_{31})$, $(-C_{12} + C_{22} + C_{32})$, and $(-C_{13} + C_{23} + C_{33})$, respectively. Notice that if PPP theory held, $(-C_{12} + C_{22} + C_{32}) + (-C_{13} + C_{23} + C_{33}) - (-C_{11} + C_{21} + C_{31})$ would be identically zero.

Table 14.3 shows the cumulative impulse response functions of ΔP, ΔE, and ΔP^*, together with the implied impulse response function for ΔR.[7] From this

7. The price level considered here is based on the WPI.

Table 14.3 **Cumulative Impulse Response Changes**

$$\Delta P_t = C_{11}(L)\varepsilon_t^P + C_{12}(L)\varepsilon_t^E + C_{13}(L)\varepsilon_t^{P^*}$$
$$\Delta E_t = C_{21}(L)\varepsilon_t^P + C_{22}(L)\varepsilon_t^E + C_{23}(L)\varepsilon_t^{P^*}$$
$$\Delta P_t^* = C_{31}(L)\varepsilon_t^P + C_{32}(L)\varepsilon_t^E + C_{33}(L)\varepsilon_t^{P^*}$$

$$\begin{bmatrix} C_{11} & C_{12} & C_{13} \\ C_{21} & C_{22} & C_{23} \\ C_{31} & C_{32} & C_{33} \end{bmatrix} = \begin{bmatrix} 1.7726 & 0.09293 & 0.005026 \\ 0.12405 & 1.09206 & -0.4756 \\ 0.5096 & -0.1907 & 1.431 \end{bmatrix}$$

$$\Delta R_t = -1.13\varepsilon_t^P + 0.804\varepsilon_t^E + 0.9513\varepsilon_t^{P^*}$$

table it is seen that a unit of innovation in the domestic price level generally leads to a 1.77 percent increase in the domestic price level. Relatively small changes in the domestic price level follow shocks in the nominal exchange rate and the foreign price level. A unit innovation in the nominal exchange rate is followed by an approximately 1.09 percent increase in the nominal exchange rate. One percent shocks in domestic and foreign price levels lead, respectively, to a 0.12 percent increase and a 0.475 percent decrease in the value of the nominal exchange rate. A unit shock to the foreign price level causes a greater change in foreign prices than do innovations in the domestic price level and the nominal exchange rate. In table 14.3, we also report the change in the real exchange rate following unit innovations in ΔP, ΔE, and ΔP^*. This cumulative change is near minus one for a shock to the domestic price level and one for a shock to the foreign price level. The estimates indicate that each unit change in the domestic and foreign price levels is followed by a unit increase in the real exchange rate. The cumulative change of innovations in the nominal exchange rate of 0.804 percent suggests that a 1 percentage point change in the nominal exchange rate will induce a 0.804 percent change in the real exchange rate.

In summary, there is again no evidence to support the idea that there is a long-run relationship between the nominal exchange rate and relative price levels, as postulated by PPP theory. Innovations in nominal exchange rate changes are followed by permanent changes in the real exchange rate. It also appears that innovations in domestic and foreign price levels lead to permanent changes in the real exchange rate.

14.7 Real Exchange Rate Movements and Productivity Growth

The earlier analysis suggests that there is no systematic tendency for the real exchange rate to revert to a constant equilibrium level after a shock. Permanent shifts in the real exchange rate can result from permanent changes in the nominal exchange rate and in domestic and foreign price levels. In this section, a popular model of real exchange rate determination proposed by Balassa (1964) is called upon to attest to the validation of the observations. The Balassa proposition suggests that when productivity advances more rapidly in a country's traded goods sector than in its nontraded sector, that is, when real shocks cause permanent changes in the price of traded goods relative to nontraded goods, the relative price levels between the home and the foreign country are subject to change. Hence, the underlying equilibrium real exchange rate is also subject to change. However, this is not the whole story, in our view. As the nominal exchange rate changes, relative labor unit costs would change when both domestic and foreign labor cost are computed in the same currency. In such a way, nominal exchange rate changes induce differences between the two countries in the growth rates of unit labor costs and then cause the real exchange rate to change. In the following section, we will investigate the movement of real exchange rates based on the model of productivity differentials. First, we briefly present the basic model used to explain long-run changes in the real exchange rate.

Following Hsieh (1982), let P and P^* denote the domestic and foreign price indexes, which are defined as the weighted averages of the prices in the traded and nontraded goods sectors:

$$P = (P_t)^{1-\alpha}(P_n)^{\alpha}, \quad P^* = (P_t^*)^{1-\beta}(P_n^*)^{\beta},$$

where α and β are constant weights between zero and unity. Then the real exchange rate can be expressed as

$$\text{(1)} \qquad \frac{EP^*}{P} = E\left(\frac{P_n^*}{P_t^*}\right)^{\beta}\left(\frac{P_n}{P_t}\right)^{-\alpha}\left(\frac{P_t^*}{P_t}\right).$$

Assuming constant returns to scale and a fixed supply of labor at home and abroad, with labor being the only factor of production, and free mobility of labor between sectors, the same nominal wage W will prevail in both sectors. Let A_t and A_n denote the average productivities of labor in the traded and nontraded goods sectors, respectively. Perfect competition among producers in both sectors ensures that prices equal average production cost:

$$\text{(2)} \qquad \begin{aligned} P_t &= W/A_t, & P_n &= W/A_n \\ P_t^* &= W^*/A_t^*, & P_n^* &= W^*/A_n^* \end{aligned}$$

Substituting equation (2) into equation (1), one obtains

$$\text{(3)} \qquad R = E\left(\frac{A_n^*}{A_t^*}\right)^{-\beta}\left(\frac{A_n}{A_t}\right)^{\alpha}\left(\frac{W^*/A_t^*}{W/A_t}\right).$$

Expressing equation (3) in logarithms, one obtains

$$\text{(4)} \qquad \begin{aligned} \ln R = {} & \alpha(\ln A_n - \ln A_t) - \beta(\ln A_n^* - \ln A_t^*) + \ln E \\ & + \ln(W^*/A_t^*) - \ln(W/A_t). \end{aligned}$$

The theory outlined above suggests that the behavior of the real exchange rate could reflect productivity growth. The first term on the right-hand side of equation (4) is the difference in growth rates of labor productivity between the domestic nontraded and traded sectors. The second term is the difference between the two foreign sectors. The third term can be considered the difference in the growth rates of unit labor cost between the two countries.

Hsieh's (1982) work uses time-series data to estimate equation (4) in order to find supporting evidence for the idea that productivity differentials between sectors can explain the behavior of the real exchange rate series. However, as there is a consensus among researchers that many economic time series have no tendency to return to an equilibrium value, we have little confidence that equation (4) provides a good approximation of the relationship among variables without a formal test of the nature of the data set. If a unit root exists in any one of the series, the statistical interpretation and properties of the least squares estimates for the model may not be valid. Thus we will consider the time-series behavior of each series individually and then investigate the possibility of a long-run equilibrium among the series.

As discussed, equation (4) provides a framework for the analysis of the real exchange rate. As far as the variables used in the model are concerned, the traded sector is manufacturing industries. Labor productivity in manufacturing is calculated by dividing the real output of manufacturing by the number of employees and work hours. The nontraded sector then is defined as the service sector only. The labor productivity of this sector is computed in a similar way by dividing the real output of the service sector by the number of workers in that sector and average work hours. The data on real output in manufacturing and services in Taiwan are obtained from the NIAQ data bank. The data on number of workers, average work hours, and wage rates are taken from the WAGE data bank. For the United States, real output information is collected from the US data bank, and the remaining elements are taken from the NIPA data bank. All these data banks are accessible in the AREMOS/UNIX economic database system maintained by the Education Ministry of Taiwan.

First, we consider the stochastic properties of the series of differences in productivity changes between the traded sectors and nontraded sectors at home and abroad, and the differences in unit labor cost changes. According to the ADF test statistic, for all the series examined, the hypothesis of a unit root could not be rejected at the 95 percent significance level. Unit root tests were applied also to the first-differenced series, and the $I(1)$ null hypothesis could be rejected for all the series, as shown in table 14.4. These findings suggest that the levels of series are $I(1)$. The Johansen cointegration approach is next performed in the VAR framework. First, different values of the lag length $k = 1, \ldots, 8$ are considered. In most cases, a lag of $k = 4$ is required to remove serial correlation in the residuals. The test for a linear trend in the nonstationary part of the process is performed by

$$-T \sum_{i=r+1}^{p} \ln[(1 - \lambda_i^*) / (1 - \lambda_i)],$$

where λ_i^* are eigenvalues obtained from cointegration analysis assuming no trend. Since a linear trend is confirmed, we proceed with the Johansen proce-

Table 14.4 **Unit Root Test for Variable Series in Equation (4)**

	Variables			
	$\ln R$	$\ln A_n - \ln A_t$	$\ln A_n^* - A_t^*$	$\ln E + \ln (W^*/A_t^*) - \ln (W/A)$
Level	−1.233	−1.868	−0.398	−0.586
First difference	−6.92	−9.80	−11.53	−6.80

Note: Real exchange rates are denominated in WPI.

Table 14.5 **Johansen Maximum Likelihood Procedure**

Null	Alternative	Statistic	95% Critical Value
Cointegration Likelihood Ratio Test Based on Maximal Eigenvalue of the Stochastic Matrix			
$r = 0$	$r = 1$	57.3693	27.0670
$r \leq 1$	$r = 2$	20.1958	20.9670
$r \leq 2$	$r = 3$	5.1362	14.0690
$r \leq 3$	$r = 4$	.8724E-3	3.7620
Cointegration Likelihood Ratio Test Based on Trace of the Stochastic Matrix			
$r = 0$	$r \geq 1$	82.7022	47.2100
$r \leq 1$	$r \geq 2$	25.3329	29.6800
$r \leq 2$	$r \geq 3$	5.1371	15.4100
$r \leq 3$	$r = 4$	.8724E-3	3.7620

dure. Table 14.5 reports the values of the Johansen test statistic for the numbers of cointegrating vectors. In the case under consideration, the hypothesis of no cointegrating vector ($r = 0$) can be rejected at the 95 percent level, indicating that the series in X_t are cointegrated, as suggested by the model. The (normalized) estimates of the equilibrium relation are given by (1, 1.16, −1.01, 0.53506). The average speed of adjustment toward the estimated equilibrium state, α, is found to be (−0.00292, −0.19305, 0.3146, −0.4048). In our case, the coefficients are significantly differently from zero with the correct signs. The results show that improvements in the productivity of the nontraded sector at home lead to long-run depreciation of the real exchange rate, a result that is the same as the Balassa (1964) analysis. Conversely, faster productivity growth in the nontraded sector abroad results in an appreciation of the real exchange rate. Furthermore, differences in unit labor cost will also cause the real exchange rate to rise.

It should be noted that a fundamental model-building point is the assumption of perfect competition. Under this assumption, prices are set equal to the marginal cost, and the prices of traded goods do not violate the law of one price. Since models of international trade have increasingly emphasized how traded goods prices are affected by market structures that deviate from perfect competition, we would also like to relax this assumption and see how the equilibrium relationship changes.

Relaxing the assumption of perfect competition in traded goods sectors only, we can see that the firms will then set a price at which marginal revenue equals marginal cost. The prices of traded goods at home and abroad represent some markup over unit cost:

$$P_t = (W/A_t)(1 + m), \qquad P_t^* = (W^*/A_t^*)(1 + m^*),$$

where m and m^* are domestic and foreign profit margins over costs. Profit margins vary because of characteristics of the market structure and changes in the macroeconomic environments. Plugging the new price equations for traded goods into the real exchange rate expression and taking logarithms, we obtain

$$\begin{aligned}(5)\qquad \ln R = {} & (1 - \beta)\ln(1 + m^*) - (1 - \alpha)\ln(1 + m) \\ & + \alpha(\ln A_n - \ln A_t) - \beta(\ln A_n^* - \ln A_t^*) \\ & + [\ln E + \ln(W^*/A_t^*) - \ln(W/A_t)].\end{aligned}$$

Equation (5) can be interpreted as saying that, as before, real exchange rate changes depend on relative changes in productivity between nontraded and traded sectors at home and abroad and on the difference between foreign and domestic changes in unit labor cost. At the same time, since marginal revenue is computed by taking profit margins into account, differences in profit margins are also linked to the real exchange rate. This relationship can be justified simply because the markup is an important measure of the competitiveness of producers.

To model markup differences in our empirical setting, we consider a time-specific effect estimation. Since markup differences are unobservable and might vary as demand and cost conditions change, we assume that the differences between markups change over time. Thus, if the links among real exchange rates, productivity differentials between the nontraded and traded sectors of the two countries, and differences in unit labor cost between the countries are close in the long run, the time-specific effect coefficients measure the changes in profit margin differential. As suggested in Greene (1993, chap. 6), the time-specific effect can be estimated by introducing dummy variables. We assume that profit margins are adjusted once every year and then estimate the model above including an additional 14 dummy variables.[8]

The estimates of the time effect are shown in table 14.6. These figures suggest that the movements of markup differentials increase as the real exchange rate changes. That is, in the short run, allowing for imperfect competition,

8. Our data span 15 years. Fourteen dummy variables were introduced since one of the time effects must be dropped to avoid multicollinearity.

Table 14.6 **Estimates of Time-Specific Effect**

Q_T	
0.40	(0.0683)
0.47	(0.0713)
0.53	(0.0736)
0.51	(0.0766)
0.71	(0.0766)
0.92	(0.0765)
1.11	(0.0814)
1.36	(0.0846)
1.52	(0.0902)
1.57	(0.0968)
1.78	(0.1090)
1.85	(0.1250)
1.94	(0.1340)
2.08	(0.1450)

Note: Numbers in parentheses are standard errors.
Equation: $\ln R_T = Q_T + \alpha(\ln A_n - \ln A_t)_T - \beta(\ln A_n^* - \ln A_t^*)_T + [\ln E + \ln (W^*/A_t^*) - \ln (W/A_t)]_T$

adjustments of markups also have something to do with real exchange rate changes.

14.8 Conclusion

In this paper, we set about analyzing the behavior of the real exchange rate. We found that the PPP relationship does not hold in the long run. Analyses of impulse response functions also suggest that changes in the nominal exchange rate and domestic and foreign price levels result in permanent changes in the real exchange rate. The empirical tests of the productivity differential model strongly support the hypothesis that it is differential productivity growth between traded and nontraded goods that leads to the observed changes in real exchange rates. Thus, if the productivity differential between the nontraded and traded sectors increases in Taiwan, the real exchange rate will depreciate. Similarly, if the productivity differential between the nontraded and traded sectors in the United States increases, the real exchange rate will decline, implying an appreciation. In addition, real exchange rates are influenced by differences in unit labor costs between the countries. In the short run, since firms in traded sectors can price to market, changes in markup differentials over traded goods prices will also have something to do with real exchange rate movements.

The lack of PPP is attributable to several factors. One of them, emphasized in this paper, is that price differentials may reflect productivity differences. Figure 14.2 shows the movements of labor productivity for the traded and nontraded sectors in Taiwan and the United States. As shown, Taiwan's labor productivity grew faster than that of the United States in both sectors. However,

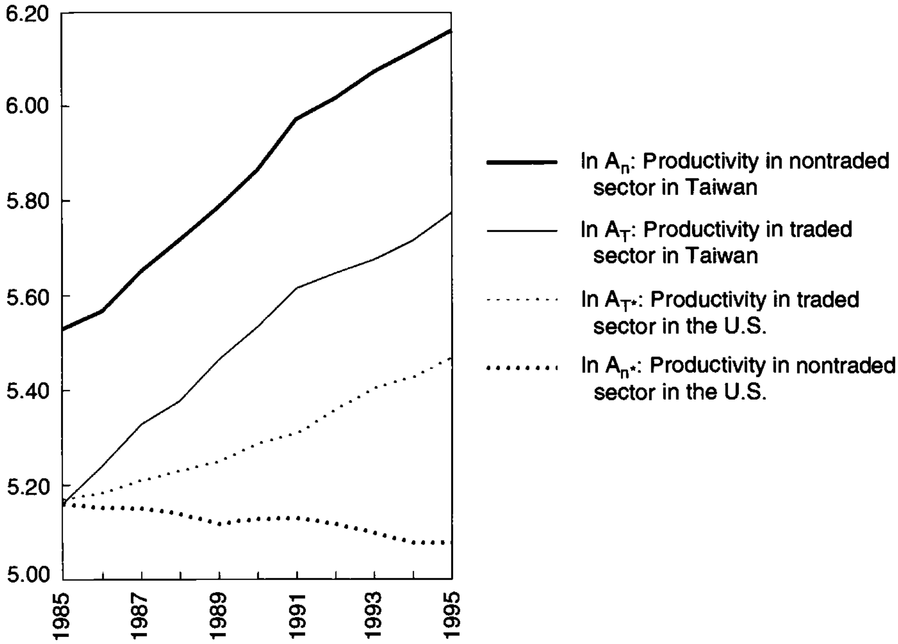

Fig. 14.2 Productivity in traded and nontraded sectors in Taiwan and the United States

far from expectations, the growth of Taiwan's labor productivity in the nontraded sector is faster than that in its traded sector. This yields a depreciation on average when the real exchange rate is denominated in WPI during the period under review.

According to our model, the growth rate of unit labor cost in the traded sectors of the two countries could also account for real exchange rate movements. Figure 14.3 shows the unit labor cost changes in the traded sectors in Taiwan and the United States. Obviously, the diagram exhibits a distinct divergence as the unit labor cost in Taiwan gets higher and higher and that in the United States declines. The differences in the growth of labor unit cost explain, to some extent, movements in the real exchange rate of the NT dollar relative to the U.S. dollar.

If we decompose changes in the real exchange rate of the NT dollar relative to the U.S. dollar, both changes in the nominal exchange rate and changes in relative price levels are responsible for changes in the real exchange rate. Differences in labor productivity growth induce price differentials so that real exchange rates are pushed upward. On the other hand, since relative wage growth in Taiwan is also increasing as the nominal exchange rate appreciates, the upward pressure on the real exchange rate is offset by wage growth movement. This yields a depreciation on average. Since the nominal exchange rate

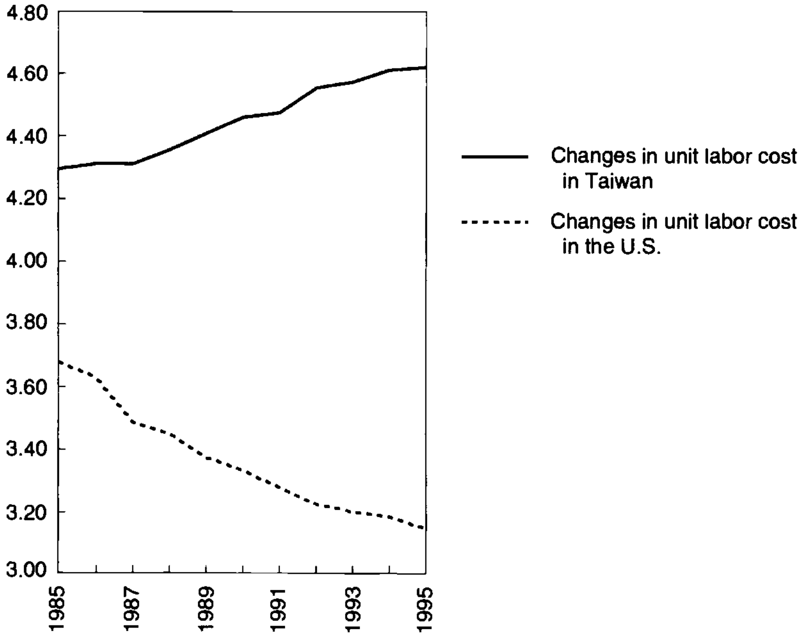

Fig. 14.3 Changes in unit labor cost in Taiwan and the United States

and domestic and foreign price levels all appear to have an effect on the real exchange rate, this implies some degree of predictability of real exchange rates.

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Comment Chi-Wa Yuen

The objective of Wu's paper is to investigate empirically the factors that determined the long-run movements of the real exchange rate between the NT dollar and the U.S. dollar over the period from January 1981 to September 1995. Using cointegration techniques, she tests (1) an implication of PPP that the equilibrium real exchange rate is time invariant[1] and (2) the Balassa-Samuelson hypothesis that differential productivity growth between the traded and nontraded goods sectors across countries is an important determinant of real exchange rate movements.

Two main results emerge from this study: (1) The nominal exchange rate is not cointegrated with relative (domestic and foreign) price levels, implying persistent deviations of the real exchange rate from its constant long-run PPP value. Innovations in the nominal exchange rate, the domestic price level, and the foreign price level each result in permanent changes in the real exchange rate. (2) Observed changes in the real exchange rate can be explained by differential productivity growth between the traded and nontraded goods sectors. In other words, the paper rejects PPP and provides support for the Balassa-Samuelson hypothesis as an explanation of divergence from PPP.

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1. The relative version of PPP implies that the rate of change of the nominal exchange rate (defined as domestic currency units of foreign currency) is equal to the excess of the domestic inflation rate over and above its foreign counterpart, i.e., $\Delta E/E = \Delta P/P - \Delta P^*/P^*$. Restated in terms of the real exchange rate R (defined as EP^*/P), it also implies that $\Delta R/R = 0$. This was examined in the earlier literature by testing the hypothesis that $a_0 = 0$ and $a_1 = -a_2 = 1$ in either one of the following regressions: (i) $\ln E = a_0 + a_1 \ln P + a_2 \ln P^* + u$ (*absolute* version); or (ii) $\Delta \ln E = a_0 + a_1 \Delta \ln P + a_2 \Delta \ln P^* + v$ (*relative* version). (The former is well known to be more restrictive than the latter.) Alternatively, one can test PPP either by directly comparing the actual exchange rates with those implied by PPP (i.e., P/P^*) or by checking the law of one price for individual tradable commodities (e.g., the *Economist*'s Big Mac index).

In fact, there are a number of familiar reasons why, a priori, we should not expect PPP to hold exactly. First, international trade is not perfectly free in the way described in textbooks, due to (a) transportation costs and trade barriers, (b) slow price and wage adjustments in goods and labor markets (especially since these markets are less integrated internationally than capital markets), and (c) the practice of discriminatory pricing under imperfect competition. Second, statistical or measurement problems exist: (a) Price differentials may reflect productivity or quality differences. (b) There is no internationally standardized basket of goods; in constructing price indexes, different weights are attached by different countries to the same good because consumption patterns differ from country to country. (c) Price indexes contain nontraded goods components, which should be excluded from tests of PPP (as PPP, based on arbitrage in international commodity markets, should hold only for traded goods).

Wu has made an effort to address some of these problems—for example, productivity differentials, WPI versus CPI, and profit margin or markup. She is especially concerned about the Balassa-Samuelson hypothesis that under differential productivity growth and wage equalization across traded and nontraded goods sectors and international equalization of prices of traded goods, higher growth in the traded goods sector at home will lead to a fall in the relative price between traded and nontraded goods, followed by a rise in the domestic price level, and ultimately a depreciation of the real exchange rate. The empirical support she finds for this hypothesis implies that the long-run divergence from PPP can be explained by differences in productivity growth between Taiwan and the United States. In addition, she finds that real exchange rate movements can be explained in part by differences in unit labor cost and adjustments of markup differentials on traded goods prices under imperfect competition in the short run.

The existing evidence on PPP is in general sensitive to the choice of time period, countries, and price index. Despite the mixed results, it is widely accepted that PPP holds better for countries with closer geographical proximity and trade linkages, for traded goods than for nontraded goods, and for the long run than for the short and medium runs. But contrary to PPP, nominal exchange rates show more volatility than the corresponding relative national price levels. It would therefore be informative to provide a more systematic comparison of the behavior of the NT dollar–U.S. dollar exchange rate with some of these general patterns.

The evidence from studies based on cointegration methods has also been mixed. But it has commonly been found that cointegration tests fail more easily under floating (rather than fixed) rate regimes, and more frequently when CPIs—which have a higher nontraded goods component—(rather than WPIs) are used as price indexes. Regarding the latter, the qualitative results in this paper do not depend much on the choice of price index. Regarding the former, as the NT dollar was pegged to the U.S. dollar prior to August 1981, the sample in this study contains data from both the fixed and floating rate periods. It is not clear why the author does not drop the relatively short (with respect to the data series) fixed rate period from her study, especially since the behavior of exchange rates can in principle be very different under the two regimes. Given the predominance of floating rate data in this paper, however, her results can be viewed as largely consistent with those from previous studies.

Bearing in mind that exchange rates and price levels are both endogenous variables determined by some other exogenous variables, one should realize that PPP is not really a *theory* of exchange rate determination. Rather, it simply suggests a *relation* among these variables that should be satisfied in equilibrium. Like the quantity theory of money, I tend to believe that PPP must hold as a long-run proposition ceteris paribus (i.e., holding constant the PPP-divergent factors mentioned above). Whatever negative evidence we may find must reflect limitations in the data or the empirical methodology. If one is willing to take such a strong view, it becomes immaterial whether the data we have support or reject PPP. What is more interesting economically is to be able to understand the quantitative significance of the various economic factors (relative money supplies and demands, volume of trade and size of capital movements, etc.) that are candidate determinants of the exchange rates. For instance, what are the distinct patterns in the movement of the NT dollar–U.S. dollar exchange rate that differentiate it from other bilateral exchange rates? What is the nature of the shocks that are responsible for the observed movement (transitory or permanent, real or monetary, aggregate or idiosyncratic, anticipated or unanticipated)? In what way is the nature of these shocks related to the institutional features in Taiwan? These are questions that I, as a participant in this "regional" conference (with an aim to understanding better the peculiarities of an Asian country like Taiwan), would most like to see addressed.

Comment Ponciano S. Intal, Jr.

In this paper, Wu sets out to evaluate the movement of the real exchange rate of Taiwan vis-à-vis the United States during the 1980s using currently popular analytical techniques like cointegration analysis. She shows that PPP does not hold for the case of Taiwan vis-à-vis the United States. Most important, Wu tested the productivity differential model of real exchange rate movements. She concludes that "it is differential productivity growth between traded and the nontraded goods that leads to the observed changes in real exchange rates" between Taiwan and the United States.

I would like to commend Wu for her meticulous analysis. I have only a few

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comments, centering on the use of data, the need to explain the real appreciation of the NT dollar using the CPI series, the empirical test of PPP theory, and the applicability of the analysis to developing country comparisons.

Use of Data

The paper states that using the WPI series, the NT dollar depreciated in real terms relative to the U.S. dollar during the 1980s. However, using the CPI series, the NT dollar appreciated in real terms vis-à-vis the U.S. dollar during the same period. The paper also states that U.S. productivity grew faster in the traded sector than in the nontraded sector relative to Taiwan during the period.

Given that U.S. productivity grew faster in the traded sector than in the nontraded sector relative to Taiwan, the productivity differential model of the real exchange rate (eq. [4]) suggests that the NT dollar would depreciate in real terms vis-à-vis the U.S. dollar. This is consistent with the real exchange rate series using the WPI but not with that using the CPI instead. It appears that the paper uses the WPI series in its analysis of the relationship between the real exchange rate and the differential in productivity changes.

I think the use of the WPI series instead of the CPI series in the analysis stands on shaky grounds. WPIs are generally heavily weighted by tradable goods, while CPIs include more nontraded goods and services. Considering that the real exchange rate is underpinned by the relative price of tradables to nontradables and considering that the paper uses the productivity of the service sector as the indicator of the productivity of the nontraded sector, I think it is only logical that it is the CPI series that should have been used in the analysis, rather than the WPI series.

Explaining the Real Appreciation of NT Dollar

Given that it is the real exchange rate using the CPI series that is the more appropriate real exchange rate to use in the analysis, then the paper would have to explain why the real exchange rate appreciated when the productivity differential model implies otherwise. This seems to suggest that there are other factors that help determine the long-run real exchange rate in addition to productivity differentials and labor cost differentials. In effect, the author may have to resort to a more complex model of real exchange rate determination (see, e.g., Edwards 1989) in order to explain the movement of the NT dollar in real terms vis-à-vis the U.S. dollar.

An alternative although rather pedestrian way to explain the real appreciation of the NT dollar is to decompose the determinants of the nominal exchange rate and of relative prices. The appreciation of the nominal NT dollar during the 1980s appears to stem from Taiwan's high saving rate and balance-of-payments surplus combined with the deregulation of Taiwan's capital account and foreign exchange market, especially after the Plaza Accord. The rise in inflationary pressure in Taiwan vis-à-vis foreign competitors can be explained using the so-called Scandinavian model of inflation whereby the balance-of-payments surplus becomes increasingly difficult to sterilize and the sharp rise in the growth of the tradable sector pushes wages and nontradable prices upward significantly.

Empirical Test of the PPP Theory

It is not surprising that the cointegration test used in the paper shows that relative PPP does not hold for the case of the NT dollar in real terms. Virtually all empirical analyses end up with the same result as long as the hypothesis is that the long-run real exchange rate is constant. This particular hypothesis requires stringent assumptions about the behavior of the real sector.

However, in view of the recent modeling efforts on the determination of the real exchange rate (see, e.g., Edwards 1989), I wonder whether the formulation of empirical tests of PPP should not be modified accordingly. Specifically, Edwards (1989) shows that the equilibrium real exchange rate need not be a constant value; rather it is a path of values satisfying simultaneous equilibrium conditions for both the external and internal sectors of an economy, given equilibrium values of other variables affecting the real exchange rate (e.g., world prices, technology, tariffs). Basically, PPP implies that monetary shocks do not have permanent real exchange rate effects. Given this, it seems that the appropriate test of "dynamic" PPP is whether there are deviations of the real exchange rate from its equilibrium path. Unfortunately, the "vector of equilibrium values" of the real exchange rate cannot be not defined exogenously; rather, it is endogenously determined within a specific model of real exchange rate determination. This may mean that the usual tests of PPP (i.e., comparison of price changes or test of deviations of the real exchange rate from zero) may have to give way to "full model" tests that take into consideration the effects of the other determinants on the equilibrium real exchange rate.

Real Exchange Rate and Productivity Differentials in Developing Countries

Some simple comparisons of real exchange rates and average labor productivity indexes among developing countries in Southeast Asia and China during the 1980s suggest that the productivity differential model of real exchange rates does not apply to developing countries. Table 14C.1 presents indexes of real exchange rates and labor productivity in selected countries. Notice that Indonesia and China registered the most significant and successful real exchange rate depreciations among the developing countries in Asia (and possibly the world) during the 1980s. Notice also that Indonesia (and most likely China also) registered significant increases in labor productivity, especially in the tradable sector (proxied by the manufacturing sector) relative to the rest of the economy. In contrast, the Philippine peso depreciated far less than the Indonesian rupiah and Chinese renminbi; moreover, the productivity improvements in the Philippine manufacturing sector were also meager.

In effect, the Philippine peso appreciated in real terms vis-à-vis the Indone-

Table 14C.1 Indexes of Real Effective Exchange Rates and Average Labor Productivity (1975 = 100)

Country	1980	1985	1990
China, People's Republic			
Exchange rate	116	195	215
Labor productivity			
Overall[a]	122	166	203[b]
Manufacturing[a]	n.a.	n.a.	n.a.[b]
Indonesia			
Exchange rate	141	162	239
Labor productivity			
Overall	126	131	140
Manufacturing	156	195	227
Malaysia			
Exchange rate	125	109	129
Labor productivity			
Overall	125	138	163
Manufacturing	104	117	161
Philippines			
Exchange rate	99	101	112
Labor productivity			
Overall	120	96	104
Manufacturing	122	107	119
Singapore			
Exchange rate	111	103	101
Labor productivity			
Overall	116	147	187
Manufacturing	114	136	189
Thailand			
Exchange rate	109	113	115
Labor productivity			
Overall	118	136	167[b]
Manufacturing	121	131	165[b]

Sources: Intal (1992a) for real effective exchange rates; Intal (1992b) for average labor productivity indexes.

Note: An increase in the value of the real effective exchange rate index means an exchange rate depreciation.

[a]Base year is 1976.

[b]1989.

sian rupiah or the Chinese renminbi. This result is in sharp contrast to the implications of the productivity differential model of real exchange rates. The key reason for this is that simple real exchange rate equations like equation (4) in the paper embody stringent explicit or implicit assumptions about the nature of factor and commodity markets, especially factor market flexibility and factor mobility, low or no tariffs and nontariff barriers, and full employment. In most cases, developing countries do not meet these conditions.

More important, in the case of successful reforming economies like Indonesia and China during the 1980s, the real exchange rate was not determined in any way by productivity differentials. Rather, real exchange rate changes were major policy decisions made in concert with other major structural reforms related to the opening up of the economy and greater deregulation of economic activities. The end result is higher productivity growth in the economy, especially in the tradable sector, and a higher economic growth rate. Thus, in this particular instance, the real exchange rate became the determinant of the change in productivity in the tradable sector and the whole economy, instead of the other way around as the productivity differential model indicates.

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