The Role of New Taiwan Dollar In the Late Stage of Twenty Century: Cointegration Test for the International Finance

Chien-Chung Nieh[a] Kuang-Cheng Cheng[b] Hong-Kou Ou[c]
E-Mail: niehcc@mail.tku.edu.tw

ABSTRACT

Exploiting the idea of Enders and Hurn (1994), this study estimates the theory of G-PPP, investigating the long-run equilibrium relationship among bilateral real rates of New Taiwan dollar and other currencies under consideration. This study improves upon previous cointegration work by implementing multivariate maximum likelihood with consideration of Johansen (1988, 1990, & 1994) five VAR models. Moreover, applying the critical value of test statistics by Osterwald-Lenum (1992) enables us to consider the system up to eleven variables which overcomes the limitation of only up to five variables as Sarno (1997) faced. The results show that all three multi-country settings are found to constitute "optimal currency area" from this empirical work. Especially for the Asian four little dragons, they are highly integrated with three cointegrating vectors (almost full rank), but in the presence of no linear trend and quadratic trend. The finding of testing on the Pacific Rim nations is consistent with Enders and Hurn (1994) that the currencies of all the nations within the Pacific basin are mutually influenced. The result also advocates that there exists a long-run equilibrium relationship among NT$ together with the currencies of seven large industrialized countries.

Key Words: NT dollar, Generalized-Purchasing Power Parity (G-PPP), Optimal currency area, Cointegration, Linear and Quadratic trend

[a] Corresponding author: Professor, Department of Banking and Finance, Tamkang University, No. 151 Ying-chuan Rd., Tamsui Dist., New Taipei City 251, Taiwan. E-Mail: niehcc@mail.tku.edu.tw
[b] PhD candidate, Department of Banking and Finance, Tamkang University, No. 151 Ying-chuan Rd., Tamsui Dist., New Taipei City 251, Taiwan
[c] PhD candidate, Department of Banking and Finance, Tamkang University, No. 151 Ying-chuan Rd., Tamsui Dist., New Taipei City 251, Taiwan

I. Introduction:

In the late stage of twenty century, Taiwan has made remarkable economic progress with an annual average economic growth rate of 7.62% for the period 1985 to 1998. Moreover, "The World Competitiveness Report (1999)" indicates that the competitiveness of this small island-economy has jumped from rank twenty-third (1998) to rank eighteenth (1997) all over the world. The boost of the volume of the foreign investment and world trade has endowed Taiwan government an ambition to develop Taiwan the Asia Pacific Regional of operations center (ROC). [1] [2] Liberalization and internationalization is the goal of the macroeconomic policy to make these operations center realized. To accelerate the financial center (one of the ROC) to be accomplished, Taiwan government has loosen restrictions on bank regulations, capital mobility limitations...and so on, from the view of international finance since 1995. The new Taiwan dollar (NT$) thus plays an important role in this international platform. The objective of this paper is to investigate the role of NT$ by employing the newly developed cointegration methodology of Johansen five VAR models based on the theory of G-PPP to estimate the long-run equilibrium relationship among NT$ and other countries' currencies.

Since the beginning of the 1980s, that the short-run PPP is inadequate to explain price and exchange-rate movements for most of the countries has largely been discussed among economics professions. Nevertheless, the long-run PPP has also enormously been examined by implementing the unit-root and the cointegration methodologies. According to them, the bilateral exchange rate and price levels of two countries must be cointegrated for PPP to hold. Otherwise, deviations from PPP in the short run are not temporary but persistent. Among those empirically evidence, Enders (1988, 1989), Corbae and Ouliaris (1988, 1991), Kim (1990), Kim and Enders (1991), and Wright (1994) all found that the long run PPP does not hold. On the contrary, researches like Patel (1990), Perron and Vogelsang (1992), Cheung and Lai (1993), Pippenger (1993), and Kugler and Lenz (1993) supported that the long run PPP holds. These mixed finding dictates that it is inadequate to interpret long run relationship between the bilateral exchange rate and countries' relative price level based on two countries setting.

In order to have complete interpretation for the interrelationship among countries' exchange rates, a currency area has to be well defined. The concept of optimum currency area, first cited by Mundell (1961), asserts that real shocks of all

[1] Taiwan has become the world's fourteen largest trading country with a foreign exchange reserve estimated at $90.3 billion at the end of 1998.

[2] The Asia Pacific Regional of Operations Center uses manufacturing center as a core, others include financial center, sea transportation center, air transportation center, media center, and telecommunication center.

countries within the currency area share common trends. This concept asked that if the arguments against the gold standard were correct, why should similar arguments not applied against a common currency system in a multi-regional country?[3] Mundell believed that the stabilization argument for flexible exchange rate is valid only if it is based on regional currency areas. Since nowadays we are indeed in an age of flexible exchange rates (post-Bretton Woods exchange rate regime), the optimal currency area should be the "region", not the "nation".

The so-called Generalized Purchasing Power Parity (G-PPP) model developed by Enders and Hurn (1994) is a theory adopting the idea of "optimal currency area", explaining the "stylized" facts of real exchange rates behavior. The G-PPP argues that although bilateral real exchange rates are generally nonstationary, they will exhibit common stochastic trends if the fundamental variables, the determinant of real exchange rate, are sufficiently interrelated.[4] As long as these interrelationships are sufficiently strong, G-PPP will hold for the set of countries under consideration and the set can be considered the domain of a currency area. Enders and Hurn (1994) found that G-PPP holds among each of the Pacific Rim nations and the large industrialized countries, whereas only mild evidence for G-PPP to hold among the Pacific Rim nations as a group. Nonetheless, Sarno (1997) tested for G-PPP among the Big-7 except Canada.[5] The results among different country settings are shown to be distinct. Some multi-country settings constitute the optimal currency area, whereas others do not.

To find the confirmation of G-PPP is to examine the long run movements among all the bilateral exchange rates. Any deviation from the long run equilibrium implies breaking the currency area. This paper applies a series of unit-root tests for stationarity various bilateral exchange rates and cointegration tests for the long-run relationship among New Taiwan dollar and other currencies under consideration, that is, a test for the existence of G-PPP. Three multi-country settings are considered: (1) the Asia four little dragons (i.e., Taiwan, Singapore, Hong-Kong, and Korea); (2) countries in the Pacific Rim as a whole which include four little dragons, four little tigers (Malaysia, Philippine, Thailand, and Indonesia), and India; and (3) Taiwan and the big seven (G-7). However, Australia Dollar is employed instead of Italy lira owing to the growing number of emigrant to Australia in this decade.[6] The methodology

[3] A system of flexible exchange rates was originally propounded as an alternative to the gold-standard mechanism, which many economists blamed for the world wide spreads of great depression after 1929.

[4] The reasons behind the linkages include technology transfers, immigration, or capital movements.

[5] The reason for Sarno (1997) to test no more than five variables in its estimations might be under the restriction of the Johansen and Juselius (1990)'s critical values for systems only up to five variables. However, employing Osterwald-Lenum (1992)'s fulfillment, we can loosen the limitation and estimate the systems for the critical values up to eleven variables.

[6] The U.S. dollar is viewed as the strongest currency and it carries 60% of Taiwan's foreign reserve. Detuches Mark, Swiss France, Japan Yen, and British Pound are the most traded currencies in Taiwan's

employed in this paper is the Johansen multivariate maximum likelihood cointegration tests, which is based on the Johansen five VAR models with the determination of cointegration rank in the presence of a linear trend and quadratic trend.

Section II presents the model of G-PPP. Data are described in section III. The methodologies of econometric background are illustrated in section IV. Section V summarizes the empirical findings and Section VI concludes the paper.

II The Model

Generalized purchasing power parity (G-PPP) elaborated by Enders and Hurn (1994) is deemed an interpretation in terms of Mundell's (1961) graceful theory of "optimal currency area". Mundell (1961) argued that, today, if the case for flexible exchange rates is a strong one, it is, in logic, a case for flexible exchange rates based on regional currencies, not on national currencies.[7] To appropriately interpret that the optimum currency area is based on the "region", Mundell used two-country case (e.g., USA and Canada) to illustrate that two regions (e.g., East and West) could constitute the domain of a currency area if they experience the common type of real shocks. This in turn confirms the stationary property for the real exchange rate within currency area. Expanding this thought to a multi-country setting, we could expect there to be at least one linear combination of the various bilateral real rates among members within the currency area to be stationary. The stationary phenomenon of the long-run equilibrium relationship among the bilateral real rates is actually the spirit behind G-PPP.

The base currency chosen is crucial for interpreting the results. The bilateral real rates used in Enders and Hurn (1994) are based on the Japan Yen. However, according to the phenomenon that a country with larger volume of trade should have more significant impact to its trade partners, this paper uses US dollar as the base currency to examine the G-PPP (Table 1).

Table 1. Comparison of the volume of trade between U.S. and Japan
(Aggregated Presentation Transaction Data: 1988-1997, in billions of dollars)

	88	89	90	91	92	93	94	95	96	97
U.S.:										
Merchandise:										
Exports f.o.b.	320.23	362.16	389.31	416.91	440.35	458.73	50.45	577.74	613.98	680.28
Imports f.o.b.	-447.19	-477.3	-498.34	-490.98	-536.45	-589.44	-668.59	-749.43	-803.23	-877.28

financial market for both spot and future markets. Moreover, Canada and Australia carry comparatively much more immigrant of Taiwanese in this decade.

[7] Under national currency areas, the flexible exchange rates does not correct balance of payment (BOP) among regions, although it will do so among countries.

Trade Balance	-126.96	-115.14	-109.03	-74.07	-96.1	-130.72	-164.14	-171.69	-189.25	-197
Service:										
Credit	111.16	127.72	147.35	163.67	177.15	184.68	195.05	216.71	234.69	251.13
Debit	-98.53	-102.54	-117.64	-118.46	-118.3	-123.1	-131.76	-143.19	-152.77	-163.72
Japan:										
Merchandise:										
Exports f.o.b.	260.88	270.99	282.31	308.17	332.57	352.66	385.7	428.72	400.28	409.24
Imports f.o.b.	-168.64	-190.87	-213.02	-212.08	-213.24	-213.24	-241.51	-296.93	-316.72	-307.64
Trade Balance	92.24	80.12	69.28	96.08	139.42	139.42	144.19	131.79	83.56	101.6
Service:										
Credit	35.37	40.26	41.38	44.84	53.22	53.22	58.3	65.27	67.72	69.3
Debit	-65.62	-76.96	-84.28	-86.63	-96.3	-96.3	-106.36	-122.63	-129.96	-123.45

notes:1.Data are from Balance of Payment Statistics Yearbook of International Monetary Fund (IMF).
2.Exportation and Importation are counted based on fare on board (f.o.b.)
3.Values are in billions of dollars
4.The table shows that the value of trade of US is almost double of that of Japan.

The G-PPP for an m-country setting in an n-country economy holds for the following relationship:

$$E_{b1t}\frac{P_{1t}}{P_{bt}}=\left(E_{b2t}\frac{P_{2t}}{P_{bt}}\right)^{\beta_{b2}}\times\left(E_{b3t}\frac{P_{3t}}{P_{bt}}\right)^{\beta_{b3}}\times\ldots\times\left(E_{bmt}\frac{P_{mt}}{P_{bt}}\right)^{\beta_{bm}}\times\nu_t \qquad .....(2.1)$$

where E_{bit} is the nominal exchange rate between country i and base country at time t, P_{it} is the aggregate price level of country i in period t, and ν is a stationary stochastic disturbance term. The condition that all β_{bi} s are equal to zero is indeed a special case merging to a well-known theory of PPP relationship.

The logarithm form of equation (2.1) describes that within the domain of the currency area, there exists a long run equilibrium relationship between their m bilateral real rates.

$$r_{b1t}=\beta_{b2}\times r_{b2t}+\beta_{b3}\times r_{b3t}+\ldots+\beta_{bm}\times r_{bmt}+\varepsilon_t \qquad .....(2.2)$$

where r_{bit} is the logarithmic bilateral real exchange rates in period t between base country and country i, β_{bi} denotes the parameter of the cointegrating vector, and ε_t is logarithm term of ν_t.

In order to explain the theory of G-PPP, we have to examine the interrelationship among the underlying fundamentals and show how the values of β_{bi} are related to the various behavioral parameters of the aggregate demand functions. The traditional goods-market-clearing dictates that, for a particular country, the aggregate demand is positively related to both domestic and foreign income (output) levels, positively related to the relative prices of foreign and domestic goods, and negatively related to the real interest rate.

$$y_{0t} = \sum_{i=0}^{m} \theta_{0i} y_{it} + \sum_{i=1}^{m} \eta_{0i} r_{0it} - \phi_0 i_t \qquad \text{.....(2.3)}$$

where number 0 indicates the base country, thus y_{0t} is log of real income level of the base country in period t; whereas y_{it} is log of the real income level for country i at time t, r_{0it} is log of the real exchange rate between base country and country i in period t, and i_t represents the world common interest rate at time t. For the parameters, θ_{00} is the marginal propensity to consume for home goods of the base country, θ_{0i} represents country i's marginal propensity to consume for import goods from base country, parameters η_{0i} is cross-price elasticity of demand between the goods of base country and country i, and ϕ_0 presents base country's marginal propensity to spend out of a change in the real interest rate.[8]

Since fundamental series are mostly found to follow a non-stationary process (unit-root), the real income (output) shocks, which are assumed to be the only disturbance in this study, are permanent ones. However, if the real income levels among countries share common trends, the stationary property of at least one linear combination of the various bilateral real exchange rates will exist. This can be represented as a reduced-form for the m+1 countries setting (including one base country):

$$R_t = A\, Y_t \qquad \text{.....(2.4)}$$

where R_t is the (m*1) vector of real exchange rates r_{0mt}, A is the (m*m+1) matrix of parameters, each of them is dependent on the various 2_{0i}, 0_{0i}, and N_0, and Y_t is the (m+1*1) vector of real income levels y_{it} (i=0,1,2,...,m).

Stock and Waston (1988) gave a good description for series sharing the common trends. That is, the vector of real income levels can be jointly determined by the m+1 nonstationary variables, which are represented as m+1 stochastic trends:

$$Y_t = \Pi \Theta_t \qquad \text{.....(2.5)}$$

where $\prod = \begin{bmatrix} \pi_{0,0} & \dots & \pi_{0,m} \\ \dots & \dots & \dots \\ \pi_{m,0} & \dots & \pi_{m,m} \end{bmatrix}$ is a (m+1 * m+1) matrix, and $\Theta_t = (P_{0t}, P_{1t}, \dots, P_{mt})'$ is a (m+1 * 1) vector of the nonstationary stochastic trends.

Combining equations (2.4) and (2.5), the behavior of the real exchange rates vector R_t can be represented by:

$$R_t = A\Pi\, \Theta_t \qquad \text{.....(2.6)}$$

Even though all the P_{it}s are nonstationary, the behavior of the real income series depends crucially on the rank of the matrix A. For instance, if the rank of A is

[8] Marginal propensity to consume (MPC): $\theta_{00} = \Delta c_0/\Delta y_0$; $\theta_{0I} = \Delta c_0/\Delta y_i$; cross-price elasticity of demand: $\eta_{0i} = \Delta y_0/\Delta(p_i/p_0)$; propensity to spend out of a change in the real interest rate: $\phi_0 = \Delta y_0/\Delta i_0$.

find to be x, then x linear combinations of various y_{it} exist, which describes that y_{it} share x common trends. Enders and Hurn (1994) argued that, in order to support G-PPP, the critical consideration is the interrelationships among the various income disturbances. As long as these interrelationships are sufficient strong, the various real rates will share a common trends, which implies G-PPP will hold within the setting of countries under consideration and this setting can be considered to constitute a domain of a currency area. This also refers a concept of "cointegration" relationship among all pairs of the real rates in the vector R_t.

III. Data

Generalized purchasing power parity theory (G-PPP) has been conducted based on the idea of Mundell's (1961) "optimal currency area". The cointegration exercises are employed to examine the G-PPP for three multi-nation settings: i) four little dragons, ii) Pacific Rim nations as a group, and iii) Taiwan together with the seven large industrialized countries which are conjectured to contribute more significant influences to the rest of the world.

Monthly data for the period 1972.01 through 1994.07, totally 271 observations for the post-Bretton Wood System-flexible exchange rate regime, are taken from International Monetary Fund's (IMF's) *International Finance Statistics (IFS)* database except data of Taiwan. The exchange rates of NT$ to US dollar are provided by the central bank of Taiwan. The aggregate price levels are the consumer price index (CPI) with the base year of 1990. Data sets include countries of Taiwan, Singapore, Hong-Kong, and Korea (i.e., Asia four little dragons), Philippines, Malaysia, Thailand, Indonesia, and India (i.e., Pacific Rim nations) and US, UK, Japan, German, France, Canada, and Australia (i.e., industrialized countries).

Since this study investigates the long-run equilibrium relationship among real series, the bilateral real exchange rate is transferred from the nominal exchange rate by adding the log of the American consumer price index (CPI) to and subtracting the log of CPI of the domestic country from the log of the US dollar price of the domestic currency.

IV Methodologies and Empirical Results:

In this paper, the theory of Generalized Purchasing Power Parity (G-PPP) developed by Enders and Hurn (1994) is re-examined on different multi-nation settings, which are presumed to constitute currency area.

We first investigate the stationarity property for each of the real rates. The Augmented Dickey-Fuller (ADF) test (equation 4.1) by Dickey and Fuller (1981) for the single unit root and Dickey and Pantula’s (1987) test (equation 4.2) for the

multiple unit roots are both employed in this study.

$$\Delta y_t = \alpha + \theta \times y_{t-1} + \gamma \times t + \sum_{i=2}^{p} \beta_i \times \Delta y_{t-i+1} + \varepsilon_t \qquad \text{.....(4.1)}$$

$$\Delta^r y_t = \theta_1 \times \Delta^{r-1} y_{t-1} + \theta_2 \times \Delta^{r-2} y_{t-1} + \theta_3 \times \Delta^{r-3} y_{t-1} + ... + \theta_r \times y_{t-1} + \varepsilon_t \qquad \text{.....(4.2)}$$

The result in Table 2 shows a mix finding. However, by natural interpretation, the macroeconomic fundamentals most likely follow the business cycle with a trend process in the real economy. Since the behavior of bilateral exchange rates is determined by fundamental variables, it should poss a time trend property and the τ_τ-statistic of ADF test is more suitable compared to the τ-statistic and τ_μ-statistic for the unit root test. As we observe from Table1, when the equation with drift and time trend (4.1) is estimated, there exists a nonstationary property for all the real rates at least at 1% significant level.

Table 2. Augmented Dickey-Fuller Tests for Univariate Single Unit Root

Group	Variables	τ (1)	τ_μ(1)	τ_τ(1)
(1 & 2)	TAIWAN	-0.5038	-2.3467	-2.7894
(1 & 2)	SINGA	0.7126	-0.0408	3.2993
(1 & 2)	HK	2.9796***	0.9720	-0.8654
(1 & 2)	KOREA	2.2849**	-2.1194	-1.2759
(2)	INDON	2.8962***	-3.0206**	-3.3083**
(2)	MALAY	1.0745	-0.6922	-1.3494
(2)	PHILI	2.8428***	-0.1561	-1.8324
(2)	THAI	0.4559	-4.1742***	-3.7233**
(2)	INDIA	-1.4773	-0.0576	-1.0741
(3)	AUSTR	-1.2127	-1.2010	2.7647
(3)	CAN	0.3333	-1.7956	-0.2223
(3)	DM	2.7377***	-1.7658	0.3139
(3)	FF	1.4317	-2.8787**	0.5765
(3)	UK	2.2802**	-3.4623**	-1.3362
(3)	YEN	0.8084	0.8336	3.8786**

notes: 1. The symbol ***, **, and *, represent the significant at 1%, 5%, and 10% levels, respectively.

2. The critical values for the ADF t-statistics are from the MacKinnon (1991) table.

3. The lag length is one for all real rates based on AIC..

4. τ (1), τ_μ(1), and τ_τ(1) are the test statistics for a unit root in the level, null of I(1), without constant, with constant, and with both constant and trend, respectively.

5. TAIWAN, SINGA, HK, and KOREA are tested for cointegration in both group-1 and group-2.

The multiple unit roots test for the order of integration was based on equation (4.2), which implies again that all the bilateral real exchange rates are series with a time trend. The time lag is adapted one for all the real rates. The expected finding is that all of the real bilateral rates are series with single unit root.

From Table 3, we see that, testing for two unit roots and three unit roots are all significant at the 1% level. We thus conclude that the real bilateral rates are all nonstationary with only single unit root.

Table 3. Tests for the Order of Integration Based on Dickey-Pantula Test

Group	Variables	$\tau_\tau(1)$	$\tau_\tau(2)$	$\tau_\tau(3)$
(1 & 2)	TAIWAN	-2.7894	-11.4674***	-19.1730***
(1 & 2)	SINGA	3.2993	- 9.2162***	-20.3603***
(1 & 2)	HK	-0.8654	-13.9536***	-20.4954***
(1 & 2)	KOREA	-1.2759	- 9.1126***	-15.8688***
(2)	INDON	-3.3083**	-10.8643***	-20.3125*
(2)	MALAY	-1.3494	- 9.6996***	-17.2207***
(2)	PHILI	-1.8324	- 8.0359***	-14.7195***
(2)	THAI	-3.7233**	-10.9020***	-21.5729***
(2)	INDIA	-1.0741	- 7.3341***	-15.7403***
(3)	AUSTR	2.7647	-11.0279***	-19.0478***
(3)	CAN	-0.2223	-10.2514***	-19.2304***
(3)	DM	0.3139	- 7.5552***	-16.0479***
(3)	FF	0.5765	- 8.9312***	-19.3319***
(3)	UK	-1.3362	-10.5735***	-18.3855***
(3)	YEN	3.8786**	-11.7869***	-20.2036***

notes: 1. The symbol ***, **, and *, represent the significant at 1%, 5%, and 10% levels, respectively.

2. The critical values for the ADF t-statistics are from the MacKinnon (1991) table.

3. The lag length is one for all real rates based on AIC..

4. $\tau_\tau(1)$ is the test statistic for a unit root in the level, I(1); $\tau_\tau(2)$ is the test statistic for a unit root in the first difference, null of I(2); $\tau_\tau(3)$ is the test statistic for a unit root in the second difference, null of I(3).

5. TAIWAN, SINGA, HK, and KOREA are tested for cointegration in both group-1 and group-2.

We further employ cointegration tests for the long run co-movement among all the real bilateral rate to describe the G-PPP. The methodologies employed is the more powerful Johansen multivariate maximum likelihood method in fully specified error correction model (MLECM) and the Johansen (1994) idea of determining the cointegration rank in the presence of a linear trend and a quadratic trend.

The elaborate works developed by Johansen (1988, 1990, 1994) have five VAR models with ECM, which are presented in the following forms:[9]

$$H_0(r): \quad \Delta X_t = \Gamma_1 \Delta X_{t-1} + \ldots + \Gamma_{k-1} \Delta X_{t-(k-1)} + \alpha\beta' X_{t-1} + \Psi D_t + \in_t \qquad (1988) \quad (4.3)$$

$$H_1^*(r): \quad \Delta X_t = \Gamma_1 \Delta X_{t-1} + \ldots + \Gamma_{k-1} \Delta X_{t-(k-1)} + \alpha(\beta', \beta_0)(X'_{t-1}, 1)' + \Psi D_t + \in_t \qquad (1990) \quad (4.4)$$

$$H_1(r): \quad \Delta X_t = \Gamma_1 \Delta X_{t-1} + \ldots + \Gamma_{k-1} \Delta X_{t-(k-1)} + \alpha\beta' X_{t-1} + \mu_0 + \Psi D_t + \in_t \qquad (1990) \quad (4.5)$$

$$H_2^*(r): \quad \Delta X_t = \Gamma_1 \Delta X_{t-1} + \ldots + \Gamma_{k-1} \Delta X_{t-(k-1)} + \alpha(\beta', \beta_1)(X'_{t-1}, t)' \mu_0 + \Psi D_t + \in_t \qquad (1994) \quad (4.6)$$

$$H_2(r): \quad \Delta X_t = \Gamma_1 \Delta X_{t-1} + \ldots + \Gamma_{k-1} \Delta X_{t-(k-1)} + \alpha\beta' X_{t-1} + \mu_0 + \mu_1 t + \Psi D_t + \in_t \qquad (1994) \quad (4.7)$$

[9] The 1990 equations (4.4 and 4.5) are from Johansen and Juselius (1990).

Tables 4 to 6 exhibit the results of the estimations for five Johansen (1988, 1990, and 1994) models, which show the number of cointegrating vectors in the presence of a linear trend and a quadratic trend. I select 5% critical value for all the test statistics. The deterministic procedure, following Table 4, goes from left to right and top to bottom and rejects a hypothesis if all hypotheses with smaller number are also rejected.

For estimating among "Asia four little dragons", Table 4 shows that all the null hypotheses H(r) for r=0, r≤1, and r≤2 are rejected at the 5% level but we do not reject the null of $H_0(r)$ for r≤3. The number of cointegration ranks is thus three without intercept, linear trend, and quadratic trend for the long-run relationship among these four nations (i.e., there exists three cointegrating vectors without drift and linear term in the model of first difference). This implies that these four advanced nations in the Asia Pacific share the same stochastic trends which are passed over from the common trends of the real fundamentals. This concludes that the G-PPP holds for these four nations and they strongly constitute an optimal currency area.

Nevertheless, the nine countries within the Pacific Rim also present a cointegration characteristic. They are cointegrated with three cointegrating vectors in the presence of an intercept and a linear trend but no quadratic trend. This finding is from Table 5 that all the null hypotheses H(r) for r=0, r≤1, and r≤2 are rejected. However, for r≤3, the null of $H_0(r)$, $H_1^*(r)$, and $H_1(r)$ are further rejected, but not the null of $H_2^*(r)$. This finding dictates that the G-PPP holds in the Pacific Basin and these countries constitute an optimal currency area.

My last test is for investigating the G-PPP among Taiwan along with seven large industrialized countries. The result exhibited in Table 6 shows that the G-PPP holds. These bilateral real rates are cointegrated with two cointegration ranks but present no linear and quadratic trend, which implies that the NT dollar does share the same stochastic trends with those seven industrialized and they constitute an optimal currency area.

Table 4. Determination of Cointegration rank in the Presence of a Linear Trend and a Quadratic Trend

Group-1

Rank	$T_0(r)$	$C_0(5\%)$	$T_1^*(r)$	$C_1^*(5\%)$	$T_1(r)$	$C_1(5\%)$	$T_2^*(r)$	$C_2^*(5\%)$	$T_2(r)$	$C_2(5\%)$
r=0	92.33	39.89	114.37	53.12	98.50	47.21	106.42	62.99	110.97	54.64
r≤1	45.29	24.31	67.30	34.91	53.24	29.68	53.65	42.44	49.08	34.55
r≤2	18.00	12.53	38.17	19.96	21.76	15.41	29.06	25.32	19.56	18.17
r≤3	**0.94**	3.84	13.73	9.24	0.19	3.76	7.48	12.25	4.34	3.74
AIC	1		1		3		1		3	

notes: 1. Group-1 includes countries of Taiwan, Singapore, Hong-Kong, and Korea.

2. $T_0(r)$, $T_1^*(r)$, $T_1(r)$, $T_2^*(r)$, and $T_2(r)$ denote the likelihood ratio test statistics for all the null of H(r) versus the alternative of H(p) which include all the cases with or without the linear trend and quadratic trend.

3. The determining procedure is to select from left to right and top to bottom and decide to reject a hypothesis

if all hypotheses with smaller number are also rejected.

4. $C_0(5\%)$, $C_1^*(5\%)$, $C_1(5\%)$, $C_2^*(5\%)$ and $C_2(5\%)$ denote 95% critical value from table-0, table-1*, table-1, table-2* and table-2 of Osterwald-Lenum (1992).

5. The bold number with underline indicates the selection of the rank in the presence of linear trend and quadratic trend.

6. VAR length is selected based on the smallest number of AIC (Akaike's Information Criterion).

Table 5. Determination of Cointegration rank in the Presence of a Linear Trend and a Quadratic Trend

Group-2

Rank	$T_0(r)$	$C_0(5\%)$	$T_1^*(r)$	$C_1^*(5\%)$	$T_1(r)$	$C_1(5\%)$	$T_2^*(r)$	$C_2^*(5\%)$	$T_2(r)$	$C_2(5\%)$
r=0	336.60	175.77	376.02	202.92	303.6	192.89	321.64	222.21	313.62	208.97
r≤1	241.66	141.20	271.73	165.58	215.92	156.00	234.37	182.82	226.42	170.86
r≤2	170.93	109.99	196.41	131.7	140.15	124.24	156.91	146.76	145.64	136.61
r≤3	107.19	82.49	129.82	102.14	97.56	94.15	**109.86**	114.9	100.79	104.94
r≤4	66.48	59.46	88.22	76.06	67.17	68.52	75.03	87.31	69.72	77.74
r≤5	41.19	39.89	61.31	53.12	39.86	47.21	51.13	62.99	43.64	54.64
r≤6	22.13	24.31	38.92	34.91	21.15	29.68	32.17	42.44	24.63	34.55
r≤7	4.76	12.53	20.01	19.96	5.22	15.41	14.04	25.32	7.43	18.17
r≤8	0.02	3.84	4.73	9.24	0.44	3.76	3.79	12.25	1.81	3.74
AIC	1		1		2		1		2	

notes: 1. Group-2 includes countries of Taiwan, Singapore, Hong-Kong, Korea, Indonesia, Malaysia, Philippines, Thailand and India.

2. $T_0(r)$, $T_1^*(r)$, $T_1(r)$, $T_2^*(r)$, and $T_2(r)$ denote the likelihood ratio test statistics for all the null of H(r) versus the alternative of H(p) which include all the cases with or without the linear trend and quadratic trend.

3. The determining procedure is to select from left to right and top to bottom and decide to reject a hypothesis if all hypotheses with smaller number are also rejected.

4. $C_0(5\%)$, $C_1^*(5\%)$, $C_1(5\%)$, $C_2^*(5\%)$ and $C_2(5\%)$ denote 95% critical value from table-0, table-1*, table-1, table-2* and table-2 of Osterwald-Lenum (1992).

5. The bold number with underline indicates the selection of the rank in the presence of linear trend and quadratic trend.

6. VAR length is selected based on the smallest number of AIC (Akaike's Information Criterion).

Table 6. Determination of Cointegration rank in the Presence of a Linear Trend and a Quadratic Trend

Group-3

Rank	$T_0(r)$	$C_0(5\%)$	$T_1^*(r)$	$C_1^*(5\%)$	$T_1(r)$	$C_1(5\%)$	$T_2^*(r)$	$C_2^*(5\%)$	$T_2(r)$	$C_2(5\%)$
r=0	281.56	141.20	291.78	165.58	305.42	156.00	254.37	182.82	296.62	170.86
r≤1	199.08	109.99	221.99	131.70	278.30	124.24	215.20	146.76	241.64	136.61
r≤2	99.58	82.49	122.48	102.14	135.80	94.15	138.11	114.90	135.23	104.94
r≤3	**50.14**	59.46	70.19	76.06	80.73	68.52	81.22	87.31	54.76	77.74
r≤4	25.80	39.89	45.04	53.12	34.99	47.21	47.10	62.99	31.56	54.64
r≤5	13.34	24.31	22.95	34.91	19.65	29.68	25.52	42.44	15.10	34.55
r≤6	5.55	12.53	10.52	19.96	8.75	15.41	13.09	25.32	4.28	18.17
r≤7	1.47	3.84	4.05	9.24	2.73	3.76	3.75	12.25	0.59	3.74
AIC	1		1		1		1		1	

notes: 1. Group-3 includes countries of Taiwan, USA, Australia, Canada, Germany, France, British, and Japan.

2. $T_0(r)$, $T_1^*(r)$, $T_1(r)$, $T_2^*(r)$, and $T_2(r)$ denote the likelihood ratio test statistics for all the null of H(r) versus the alternative of H(p) which include all the cases with or without the linear trend and quadratic trend.

3. The determining procedure is to select from left to right and top to bottom and decide to reject a hypothesis if all hypotheses with smaller number are also rejected.

4. $C_0(5\%)$, $C_1^*(5\%)$, $C_1(5\%)$, $C_2^*(5\%)$ and $C_2(5\%)$ denote 95% critical value from table-0, table-1^*, table-1, table-2^* and table-2 of Osterwald-Lenum (1992).

5. The bold number with underline indicates the selection of the rank in the presence of linear trend and quadratic trend.

6. VAR length is selected based on the smallest number of AIC (Akaike's Information Criterion).

V. Conclusion Remarks:

In this study, NT$ has been investigated for the long-run equilibrium relationship together with other currencies under consideration. To make the financial center (one of the regional operation center (ROC)) realized, Taiwan government has loosen some restrictions from the view of international finance since 1995, and thus NT$ plays an important role. Those countries conjectured to share the common trends with Taiwan are precisely considered for constituting the currency area. Totally sixteen countries are considered and three multi-country settings are advocated in this paper. This paper improved the previous empirical studies including Enders and Hurn (1994) and Sarno (1997) by implementing the newly developed cointegration methodologies for Johansen five VAR models and applying Osterwald-Lenum (1992) critical values for the system up to eleven variables. All the results show that all three multi-country settings do constitute optimal currency areas but they present different time paths of co-movement (i.e., in different presence of linear trend and quadratic trend).

The multi-country settings merged in this paper are Asian four little dragons, Pacific Rim nations as a whole, and Taiwan together with seven large industrialized countries. All three groups are found to constitute optimal currency areas. This implies that the G-PPP holds for all these groups. However, the co-moving style explained by the number of cointegration ranks and the presence of a linear trend and a quadratic trend shows the different degree of interrelationship. The findings of group-1 tell us that no intercept, linear trend, and quadratic trend exists in the co-movement of the time paths among the real rates of Asian four fast growing countries. Three cointegrating vectors among these four variables indicates a strong interrelationship among these four bilateral real rates (almost exhibit a full rank of four). Testing for the Pacific Rim nations, we find three cointegration ranks among these nine real rates. This indicates that the Pacific Rim nations can be considered as a domain of optimal currency area. This finding is consistent with Enders and Hurn (1994). Their real rates are interrelated but not strongly integrated as Asian four little dragons. The co-movement of these real rates presents an intercept and a linear trend but no quadratic trend. The G-PPP also holds for the third multi-country setting. NT$ together with those currencies of seven large industrialized countries are integrated with two cointegration ranks without presence of intercept, linear trend, or quadratic trend.

Since G-PPP is believed to be a useful building block for the study of price and

exchange rates behavior, further research should address on the issue of identifying the fundamentals, which determine real exchange rates and provide links among countries within a currency area. To develop a mechanism to construct a model between real exchange rate and all the fundamentals is also encouraged. The possible fundamentals might include real income shocks, price shocks, money supply increments, changes in interest rate differentials, capital movements, changes in the volume of foreign reserve, and technology improvements, etc. The weighed average of real rates of countries within a currency area to express one certain real rate is also an interesting topic for the future study. Within a currency area, there must exist certain degree of influences from country to country. Future research can also address on the issue to examine the degree of interrelationships among countries.

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