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Nonlinear Effect of Exchange Rates on Trade Balance: A Recommendation for Emerging Countries' Exchange Rate Policy

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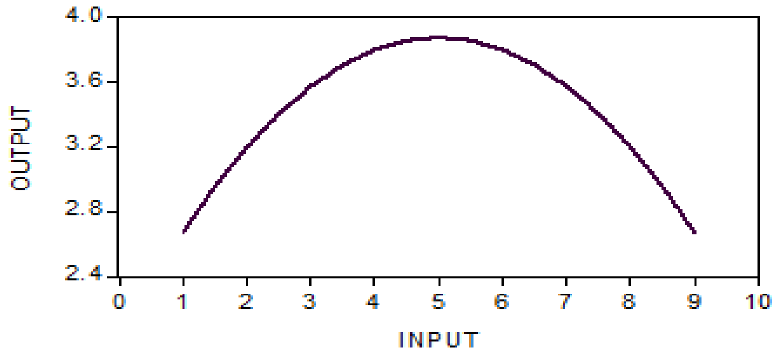
Abstract: Purpose: Considering the mixed results of previous empirical studies with regard to how the real exchange rates affect bilateral trade balance, this study intends to test the presence of not only the nonlinear relationship but also the J-curve effect and Korea data from January 1985 through December 2013 is adopted. The findings are helpful for emerging countries to evaluate their exchange policy. Methodology: Unit root test, cointegration analysis and Vector Autoregressive Error Correction Model are adopted in this study. Findings: The results indicate that there is a co-integration relationship between real exchange rates and bilateral trade balance in both linear and nonlinear models and Korea-U.S. bilateral trade balance exhibited no J-curve effect when the Korean won depreciated against U.S. dollar. A performance evaluation proves nonlinear model is better than linear model. Recommendation: The findings help us to realize that depreciation has a limited effect on promoting trade balance. Sharp currency depreciation will hurt country's trade balance.
Keywords: Exchange rate; Trade balance; Non-linear model; Co-integration.
JEL Classification: F19; F31.

1. Introduction

Devaluation of currency is hypothesized to help increase exports while decreasing imports, and subsequently improve the trade balance. Following recently high depreciating Japanese Yen, some emerging countries, especially Asian countries, may plan to depreciate their currencies. However, empirical results of how exchange rates are connected to trade balance remains mixed. Some empirical studies, such as those conducted by Yusoff (2010), Kim (2009) and Tsen (2011), support depreciation increases trade balance. Still other researchers challenged the afore-mentioned positive effect and concluded that there is no significant relationship whatsoever between the trade balance and real exchange rates (Buluswar *et al.*, 1996; Moosa, 2011; Wilson, 2000) . Some empirical findings presented by scholars such as Chiu *et al.* (2010), Sun and Chiu (2010) and Shahbaz *et al.* (2012) suggested some negative effects of depreciation on trade balance.

Even though most of the empirical studies support the argument that deprecation can improve trade balance, however, these studies did not answer the questions of "why long-run, continuous devaluations remain unobserved in many countries" and "why some studies support no or negative effects of depreciation." These two questions may be solved by exploring the nonlinear relationships between real exchange rates and trade balance. Figure 1 indicates that the input (for example, real exchange rate) will be positively related to the output (for example, bilateral trade balance) if the input value is smaller than 5, but negatively related to the output when the input value is larger than 5.

Fig-1. Nonlinear relationship between two variables



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If the input value stays in a range between 3 and 7, the input and output may be statistically irrelevant.

Figure 1 helps us to understand that if there exists a nonlinear relationship between real exchange rates and bilateral trade balance, continuous depreciation will not benefit trade balance and the relationship between exchange rate and trade balance depends on the status of the exchange rates being studied.

This does help us know “why long-run, continuous devaluations remain unobserved in many countries” and “why some studies support no or negative effects of depreciation.”

The main objective of this article is to examine a nonlinear relationship between real exchange rates and bilateral trade balance. The natural logarithm of Korean real exchange rate against US dollar was adopted in this study because it fluctuated drastically and was suitable for testing the nonlinearity; besides that many Asian countries are competing with Korean products in U.S. and European markets, the findings may have tremendous value for those Asian emerging countries to examine their exchange rate policy. As for the structure of this article, it begins with a literature review, followed by the formulation of a model to be estimated, empirical results and conclusions.

2. Literature Review

Among the theories regarding how the real exchange rates are connected to bilateral trade balance, the most cited are the elasticity and absorption theories. The elasticity theory proposed that the effect of devaluation on trade balance depends on the elasticity of exports and imports, which is known as Marshall-Lerner Condition. For devaluation to positively affect the trade balance, the Marshall-Lerner Condition requires that the absolute value of the sum of import and export demand elasticity must exceed unity. Empirical studies do not consistently support devaluation can increase trade balance. Some studies support the positive relationship, such as Bahmani-Oskooee and Wang (2006), Narayan (2006), Matesanz and Fugarolas (2009), Yusoff (2010), Tsen (2011) and Vijayakumar (2014) that examine the bilateral trade of some countries with U.S.A. These countries being studied are mainly developing countries such as India, Argentine, China, Malaysia and Sri-Lankan. On the other hand, Buluswar, Buluswar *et al.* (1996) and Moosa (2011) do not find evidences to support this positive relations when examine exchange rate of India and China. Negative relation is found in some studies such as Chiu *et al.* (2010) found that a devaluated U.S. dollar harmed America’s bilateral trade balance with 13 trading partners but improved that balance with 37 other partners. Shahbaz *et al.* (2012) evidenced a negative relation while analyzing quarterly data covering from July 1980 to June 2006 of Pakistan.

Studies focusing on Korea-US have different results, Wilson (2000); Hwang and Im (2009) do not find long-term positive effect. On the contrary, Wilson (2001) and Kim (2009) evidenced the existence of positive effect.

Not only exchange rate influences trade balance, national income also affects trade balance. According to the absorption theory, the trade balance is affected by income from both domestic and foreign sources. The effect of domestic income on trade balance is uncertain. Increases in the domestic income not only reduce trade surplus by bolstering the demand for imported goods, but also drive up production for import substitution, which leaves imports dwindling. The effect of foreign income on trade balance is also uncertain. An increase in foreign income will lead to more exports by the domestic country, but also an increase in foreign income may lead to more local substitute which reduces imports by the foreign country. Empirical studies are mixed. Hwang and Im (2009) overview related data covering from 1998 to 2008 without adopting any econometric model and conclude that world demand channel has the most influential and long-effect for the recovery of Korea exports. Tsen (2011) find Malaysia income has a negative impact on trade balance and U.S.A. income has a positive effect on bilateral trade balance. Kim (2009) find a negative effect from Korea income and no effect from U.S.A. income when examine the Korea-U.S.A trade balance. Yusoff (2010) find both Malaysia income and U.S.A income have positive effects on the bilateral trade balance.

3. Research Methodology

3.1. Sample Period

The paper focuses on the model selection of linear model and nonlinear model covering period from January 1985 to December 2013. For this purpose, we establish the linear model and nonlinear model from samples covering from January 1985 to December 2012 and compare models’ performance based on the root mean squared error and mean absolute error of 12 months covering from January 2013 to December 2013.

3.2. Definitions of Variables

Based on elasticity theory and absorption theory, exchange rate and income should be adopted as explanatory variables. This study aims to verify the nonlinear relationship between real exchange rate and trade balance; therefore, we have domestic income and foreign income as control variables. The bilateral trade balance (E/M) is denoted by $(E/M)_t$, where E_t and M_t are the US-Korea export and import values (in billions of US dollar), respectively. The bilateral trade balance, which is a ratio in nature, is irrelevant to the unit measurement and can be interpreted in either real or nominal terms. The trade balance is transformed into natural logarithms, *LNEM*, for estimation in this study. The real exchange rate (*RER*) is in the natural log-transformation as $\ln(RER_t)$, $\ln(ER_t*(CPI_{us,t} / CPI_{ko,t})$, where ER_t is the monthly exchange rate of Korean won against U.S. dollar; $CPI_{us,t}$ is the U.S.

consumer price index (2005=100) and $CPI_{ko,t}$ the Korean consumer price index (2005=100). An increased *RER* results in the depreciation of real exchange rate of Korean won. The real exchange rate square (RER^2) is the squared value of *RER* that measures the nonlinear relationship between real exchange rates and bilateral trade balance. The industrial production index (*IPI*) serves as a proxy measure of the domestic and foreign income because the real GDP statistics are available only on a quarterly basis, while the other variables in this study are available on a monthly basis. We adopted this proxy measure following the examples of Wilson (2001), Sun and Chiu (2010) and Tsen (2011). The Korean and American industrial production indices, as the Korean national income and U.S.A national income, denoted respectively by KY_t and AY_t, are also factored into this study (2005=100). All the data were collected from the Taiwan Economic Journal (TEJ) Database.

Figure 2 and 3 displayed plots of the two series from January 1985 to December 2013: *RER* and *LNEM*. Figure 2 shows the Korean won strongly depreciated against U.S. dollar from November through December in 1997 and steadily appreciating till the 2008 Financial Crisis. In Figure 3, most of *E/M* ratios exceed one; therefore, most of the *LNEM* values are above-zero, and the minimum of which (-0.32) was registered in March 1997 before the 1997 Asian Financial Crisis. Figure 4 displays the relationship between trade balance (*LNEM*) and real exchange rate (*RER*), along with an interestingly nonlinear and parabolic relationship between these two series. That relationship will be further examined by co-integration analysis and vector error correction model.

Fig-2. Scatter of natural logarithm real exchange rate of Korean Yuan/ US Dollar

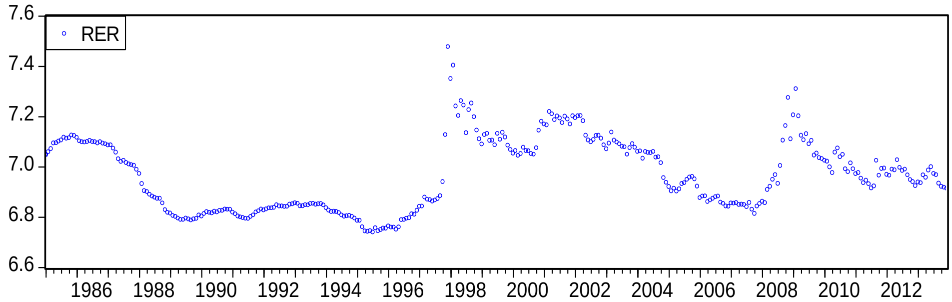


Fig-3. Scatter of Korea bilateral trade balance with US

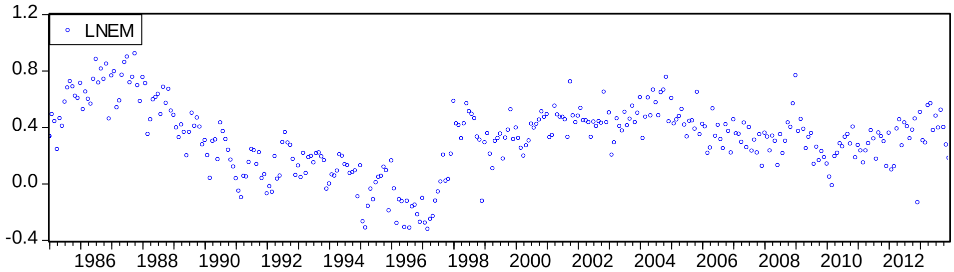
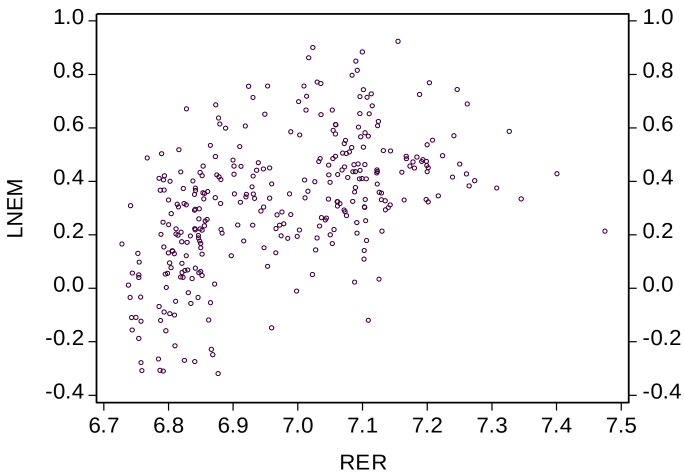


Fig-4. Scatter of Korea/ US real exchange rate and trade balance



3.3. The Estimation Models

To verify the stationarity of the variables, we perform several unit-root testing procedures and, particularly, the tests of Augmented Dickey and Fuller (1979), Philips and Perron (1988) tests.

The multivariate co-integration test suggested by Johansen (1991) features a maximum likelihood estimation procedure that examines the presence of co-integrating vectors in a Vector Autocorrelation (VAR) system, with the error correction model measuring the short-run impacts of real exchange rates on trade balance.

In this study, the long-run equilibrium relation between the two variables of "trade balance" and "real exchange rate" was examined by two equations. The first equation shows a liner relationship between real exchange rate (*RER*) and trade balance (*LNEM*), while the second one implies a non-liner relationship between real exchange rate (*RER*) and trade balance (*LNEM*). Variables in both equations had been addressed in some of the recent studies (Goswami and Junayed, 2006; Matesanz and Fugarolas, 2009; Wilson, 2001; Yusoff, 2010), except the nonlinear term in Equation (2).

$$LNEX_t = \alpha_0 + \alpha_1 RER_t + \alpha_2 KY_t + \alpha_3 AY_t + \varepsilon_t \quad (1)$$

$$LNEX_t = \beta_0 + \beta_1 RER_t + \beta_2 RER^2 + \beta_3 KY_t + \beta_4 AY_t + \mu_t \quad (2)$$

Both Equation (1) and (2) are co-integrating equations normalized on a trade balance to outline the long-run relationships among variables involved. The expected signs of coefficients in Equation (1) are stated as follows: as for the impact of real exchange rates on trade balance, it is expected that a higher real exchange rate would lead to Korean won depreciation and the subsequently expanded demand for Korean products as they appear cheaper than the U.S. ones. Therefore, α_1 is expected to be a positive value, which is a positive coefficient hypothesis based on findings proposed by researchers such as Wilson (2001) and Kim (2009). Since the impact of domestic income and foreign income are dependent on the relative strength of demand and supply, the values of α_2 and α_3 may be either positive or negative (Kim, 2009; Tsen, 2011). An increase in domestic income will promote more imports by the domestic country; also an increase in domestic income may increase the production of import substitute goods that results import decrease. By the same argument, the sign of α_3 may be negative or positive.

The expected signs of coefficients in Equation (2) are the same for variables in Equation (1), namely *RER*, *KY* and *AY*. The coefficient of RER^2, or the square term of real exchange rate, β_2 is expected to be negative. A depreciated Korean won may at first improve the trade balance, but that relationship becomes reverse when the depreciation continues. There are three possible reasons behind such a nonlinear relationship. Firstly, deprecated Korean won increases the material cost of importing goods from other countries, and a high material cost makes exported goods less attractive price-wise, hence the reduced export value. Secondly, other countries may depreciate their exchange rate in order to compete with Korea, leaving Korean products less competitive and Korea's exports dropping in value (*EX*). Thirdly, the product differentiation and demand constraint lower the demand for Korean products. For example, when the Korean won depreciates by 20% against the U.S. dollar and the Korean-made cars become 20% cheaper, those who prefer German-made cars or already own Korean-made cars will not buy Korean cars even the Korean-made cars are cheaper. Figure 4 offers a rough sketch of the nonlinear relationship between real exchange rates and trade balance, where the positive β_1 value and negative β_2 value fit the nonlinear relation.

After investigating the co-integration test results, a dynamic Error Correction Model (ECM) was established to measure the short-term impacts of variables on trade balance. Equation (3) and (4) show the linear and nonlinear relationships, respectively:

$$\Delta LNEM_t = \phi_0 + \upsilon EC_{t-1} + \sum_{k=0}^{ny} \lambda_k \Delta LNEM_{t-k-1} + \sum_{k=0}^{nl} \delta_k \Delta RER_{t-k} + \sum_{k=0}^{ne} \eta_k \Delta KY_{t-k} + \sum_{k=0}^{nm} \gamma_k \Delta AY_{t-k} + \tau_t \text{ --- (3)}$$

$$\Delta LNEM_t = c + \omega EC_{t-1} + \sum_{k=0}^{ny} b_k \Delta LNEM_{t-k-1} + \sum_{k=0}^{nl} d_k \Delta RER_{t-k} + \sum_{k=0}^{nc} e_k \Delta RER^2{}_{t-k} + \sum_{k=0}^{ne} f_k \Delta KY_{t-k} + \sum_{k=0}^{nm} g_k \Delta AY_{t-k} + \kappa_t \text{ --- (4)}$$

The regression coefficients in Equation (3) and (4) indicate the short-run effects while the coefficient of error correction term (EC) captures the short-run effects of long-run dynamics. The error correction term (EC) also shows how the system converges to a long-run equilibrium between exchange rates and trade balance. The coefficient of error correction term (EC) with statistical significance offers robust evidence of the co-integrating relationship of I (1) series in the equation.

4. Empirical Results

4.1. Stationary test

According to the results of ADF and PP unit root tests, as shown in Table 1, all variables are stationary not in the levels but in the first differences. Moreover, all the variables are integrated of order one, I (1).

Table-1. Unit Root Testing Results

Variables	Intercept /trend	Level ADF value	Level PP value	1 st difference ADF value	1 st difference PP value
LNEM	None	-1.67	-1.53	-4.85***	-29.5***
	Intercept only	-2.57	-3.34	-4.86***	-30.3***
	Intercept and trend	-2.52	-3.35	-4.86***	-40.5***
RER	None	-0.25	-0.25	-18.3***	-18.2***
	Intercept only	-2.40	-2.40	-18.3***	-18.3***
	Intercept and trend	-2.46	-2.46	-18.3***	-18.3***
RER^2	None	-0.29	-0.29	-18.2***	-18.3***
	Intercept only	-2.46	-2.46	-18.4***	-18.3***
	Intercept and trend	-2.52	-2.52	-18.4***	-18.3***
KY	None	3.77	3.77	-11.3***	-17.0**
	Intercept only	0.68	0.38	-17.7***	-17.8***
	Intercept and trend	-2.15	-2.16	-17.8***	-17.8***
AY	None	1.60	1.63	-4.02***	-18.3***
	Intercept only	-1.04	-1.23	-4.92***	-18.2***
	Intercept and trend	-2.50	-2.69	-4.92***	-18.2***

Notes: *** Indicates significance at 1% level.

4.2. Co-integration Tests

Johansen framework of multivariate co-integration (Johansen, 1991) is used to test the presence of any long-run equilibrium relationship in the variables in Equation (1) and (2). From Table 2, both the trace and maximum eigenvalue statistics indicated a long-run relationship among variables, with the null hypothesis of no co-integration rejected at the 5% significant level in both equations.

Table-2. Johansen cointegration tests

	Equation (1): Linear Model				Equation (2): Nonlinear Model			
	Trace statistic		Eigenvalue		Trace statistic		Eigenvalue	
Null Hypothesis: Number of Cointegration	Stat. value	Probability	Stat. value	Probability	Stat. value	Probability	Stat. value	Probability
None	72***	0.0008	43***	0.0009	86***	0.0014	34.8**	0.039
$R \le 1$	28.7	0.2030	16.6	0.3658	52	0.0216	25	0.08
$R \le 2$	12.1	0.3046	10.4	0.3609	18.6	0.5204	21	0.6094
$R \le 3$	1.65	0.1984	1.65	0.1984	7.23	0.5498	14.3	0.4920

1. The Johanson's cointegration test is carries out with the model of no deterministic trend and includes intercept for Equation 1 and 2.
2.***Rejection of null hypotheses at 1% level., **Rejection of null hypotheses at 5% level.
The results of normalized co-integrating vectors are listed as follows (Note: the t-statistics are in parentheses and * indicates a 1% significant level):

$$LNEM_t = 0.898RER_t + 0.025KY_t + 0.020AY_t \qquad (5)$$

(5.62*) (8.32 *) (4.85*)

$$LNEM_t = 51.13RER_t - 3.59RER^2{}_t - 0.002KY_t + 0.0005AY_t \qquad (6)$$

(2.26*) (-2.22*) (-1.12) (0.13)

From Equation (5) and (6), the estimated coefficients for long-run relationships between trade balance (*LNEM*) and real exchange rate (*RER*) do show results as expected. From Equation (5), depreciating Korean won contributes to Korea's trade balance, which is consistent with the findings of Wilson (2001) and Kim (2009). Given the significantly negative coefficient of the squared value of real exchange rate (RER^2) in Equation (6), the hypothesis of a non-linear relationship between trade balance and real exchange rates is verified. The positive coefficient value of *RER* and negative coefficient value of RER^2 show us that depreciated Korean won improves the Korea-U.S. bilateral trade balance at first but harms it when the depreciation continues. Deep depreciation may worsen trade balance which is consistent with findings of Chiu *et al.* (2010) and Shahbaz *et al.* (2012). The evidenced nonlinear relationship is different from previous studies that focus on linear relation.

The coefficients of domestic income (*KY*) and U.S. income (*AY*) in Equation (5) are all significantly positive. In other words, the increase of Korea income and U.S. income will increase the trade balance of Korea from U.S.A.

Following the economic growth of both countries, the trade surplus may become larger. After adding the RER^2, both domestic income (*KY*) and U.S. income (AY) are not significantly different from zero. We compare the forecast performance of both models in model selection section.

4.3. Error Correction Models

Since the co-integration tests suggest a long-run equilibrium relationship, the error correction models were evaluated to determine the equations' short-run dynamics. The results of Vector Error Correction Model (VECM) are shown in Table 3. The lags number for Equation (3) and (4) are 5. Insignificant coefficients from the regression were eliminated.

Table-3. Results for error correction models

	Equation (3): Linear Model				Equation (4) : Nonlinear Model		
variable	Lags	coefficient	t-value	variable	Lags	coefficient	t-value
ECT^1		-0.126	-3.20**	ECT^2		-0.035	-2.17**
$\Delta LNEM$	1	-0.496	-8.31**	$\Delta LNEM$	1	-0.563	-9.93**
	2	-0.255	-3.77**		2	-0.307	-4.66**
	5	-0.136	-2.47**		5	-0.16	-2.87**
ΔRER	1	0.52	2.56**	ΔKY	1	-0.012	-2.25**
	2	0.42	2.13**				
ΔKY	1	-0.014	-2.58**				
Adj. R^2		0.323		Adj. R^2		0.302	

** Indicates significance at 5% level.

$$ECT^1 : LNEM_{t-1} - 0.898RER_{t-1} - 0.025KY_{t-1} - 0.020\,AY_{t-1}$$

$$ECT^2 : LNEM_{t-1} - 51.13RER_{t-1} + 3.59RER^2{}_{t-1} + 0.002KY_{t-1} - 0.0005AY_{t-1}$$

The negative and significant coefficients of error correction term (ECT) further proved the co-integration among variables in Equation (1) and (2).

The linear model indicates that real exchange rate has a significantly positive, short-run effect on bilateral balance in the first and second lags. That means depreciating the Korean won immediately helps improve the U.S.-Korea trade balance. The ΔLNEM is also significantly affected by its lags.

The result of nonlinear model shows that EC term and ΔLNEM lags are still significantly affects ΔLNEM.

4.4. Model Selection

Besides the squared value of real exchange rate (RER^2) exhibited a significant effect on trade balance in the co-integration analysis (long-run), we want to compare the performance of linear model, nonlinear model and random walk. We adopt Root Mean Squared Error (RMSE) and Mean Absolute Error (MAE) to evaluate the model performance and the definition of RMSE and MAE as follows:

$$\text{RMSE} = \sqrt{\sum (Y - \hat{Y})^2 / N}$$

$$\text{MAE} = \frac{1}{N}\sum \left|Y - \hat{Y}\right|$$

Where Y is the actual value, $\hat{Y}$ is the predicted value and N is the number of prediction. In this study, the forecasting period is from January 2013 to December 2013 which means that the value of N is twelve.

Table-4. Results of performance criteria

	Linear Model	Nonlinear Model	Random Walk
Root Mean Squared Error	0.1791	0.1758	0.4196
Mean Absolute Error	0.1487	0.1442	0.3691

According to the results shown in Table 4, nonlinear model outperforms linear model and random walk that once again verifies nonlinear model is more suitable to describe the relationship between exchange rate and trade balance of US-Korea.

5. Conclusions

This paper offers a fresh insight into the relationship between real exchange rates and trade balance, while the nonlinear relationship helps us to explain the mixed results of previous studies.

Korea's highly fluctuating exchange-rate data was analyzed in this study in order to verify the nonlinear relationship between real exchange rates and trade balance. As for the analysis tools, we employed the co-integration analysis, a vector error correction model, and a comparison of forecast performance. Econometric models involve the bilateral trade balance, bilateral real exchange rate, and the domestic/foreign income of Korea and the U.S. The analysis findings showed that both linear and nonlinear equations met the requirements of co-integration. The forecast criteria results favor the nonlinear equation, which means that the effect of depreciation on trade balance is limited.

This paper purposed that the effects of depreciation differ among countries because each country has a distinctive status of real exchange rates. The findings of this paper will hopefully shed light on why the previous studies delivered mixed results, with nonlinear factors expected to be factored into future studies.

The findings also offer developing countries a new insight into the effect of depreciation that appropriate appreciation may benefit the trade balance at the beginning, but huge appreciation will damage trade balance.

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