Dynamic Analysis of Trade Balance and Real Exchange Rate: A Stationary VAR Form of Error Correction Model Approach

Yun-Yeong Kim *

This paper analyzes the dynamics of trade balance and real exchange rate based on the elasticity and purchasing power parity (PPP) approaches. Here, a stationary vector autoregressive model with cointegration error, transformed from the error correction model in Kim (2012), is employed. Trade balance and PPP are jointly considered as the two long-run cointegration relationships that represent external economy equilibria. The model was applied to the dynamic analyses of Korea's trade balance using monthly data from 1990, where model variables from the elasticity and PPP approaches were selected. Based on the estimation, we first confirmed the finding of Cheung *et al.* (2004), whereas trade balance is additionally considered. The nominal exchange rate adjustment, not the price adjustment, is the key engine that governs the speed of PPP convergence, and the nominal exchange rates were found to converge much more slowly than the prices. The nominal exchange shock did not significantly affect trade balance, whereas the price shocks did. Therefore, manipulation of the nominal exchange rate through intervention to improve trade balance might not be an effective policy tool.

Keywords: Trade balance, Real exchange rate, Error correction model, Stationary VAR

JEL Classification: F3

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I. Introduction

Trade balance is mainly determined by real exchange rate based on elasticity approach, which reflects the relative price levels between two transacting countries. In particular, at trade equilibrium, the necessary condition for improvement of trade balance after an increase in real exchange rate is the well-known Marshall-Lerner condition. The dynamic relationship between real exchange rate and trade balance is substantiated by the J-curve effect, which predicts a trade deficit in the short-run and a trade surplus in the long-run after a depreciation shock.

This kind of dynamic analysis of real exchange rate and trade balance involves the vector autoregressive (VAR) model that links directly the real exchange rate and trade balance. For instance, the traditional impulse-response analysis from real exchange rate shock to trade balance was conducted using such VAR models (Goldstein and Kahn 1985; Rose and Yellen 1989; Moura and Silva 2005; Hsing 2008).

In another perspective, we can consider the J-curve effect and the convergence of real exchange rate from that in a convergence process to cointegration equilibrium because economic theories generally do not know about the specific convergence process in equilibrium. In this respect, Pesaran and Shin (1996, 1998) proposed the persistence profiles and impulse-response analyses as indicators of the adjustment speed in a cointegrated VAR model. Another interesting application is the purchasing power parity (PPP). Engel and Morley (2001) showed that nominal exchange rates converge slowly, whereas prices converge relatively fast, by formulating the adjustment equations as a state-space model. Using the error correction model (ECM), the persistence profiles, and the generalized impulse-response analyses by Pesaran and Shin (1996, 1998), Cheung *et al.* (2004) discovered that the nominal exchange rate adjustment (not the price adjustment) is the key engine that governs the speed of PPP convergence, and the nominal exchange rates are found to converge much more slowly than prices.[1] This finding is very important in international or open macro-economic theory because it challenges conventional price-stickiness theories and raises new problems in modeling of PPP disequilibrium dynamics, essentially driven by the nominal exchange

[1] Kim (2003) also addressed the measurement of period for long-run equilibrium in a cointegration relationship. He found that the length of the long-run period for the consumption–income relationship in U.S., Germany, and Japan is approximately two to three years.

rate.

However, the aforementioned persistence profile approach mainly focused on the impulse-response (of cointegration error) analysis based on the Beveridge-Nelson decomposition. In addition, the Granger causality test and optimal forecasting of cointegration error are useful tool kits for the dynamic analyses of co-integration error dynamics. Thus, another useful option along this direction is to apply the VAR approach of Sims (1980), which includes a cointegration error as a model variable. Such approach could be made possible if ECM is transformed into a VAR form of cointegration error and stationary variables, which allow more direct exploitation of the rich tools of VAR analyses (*i.e.*, Granger causality test, impulse-response analysis, variance decomposition, and optimal forecasting).

In this respect, this paper analyzes the dynamics of trade balance and real exchange rate based on elasticity and PPP. For this study, a VAR model with cointegration error transformed from ECM in Kim (2012) or Kim and Park (2008) is utilized. Trade balance and PPP are jointly considered as the two long-run cointegration relationships that represent external economy equilibria. The model was applied to the dynamic analysis of Korea's trade balance using monthly data in 1990-2008, where the model variables are obtained from the elasticity and PPP approaches. Based on estimates, we first confirmed the finding of Cheung *et al.* (2004), whereas trade balance was additionally considered. The nominal exchange rate adjustment (not the price adjustment), is the key engine that governs the speed of PPP convergence, and the nominal exchange rates are found to converge much more slowly than prices. Nominal exchange shock does not significantly affect the trade balance, whereas price shocks do. Therefore, nominal exchange rate manipulation through intervention to improve trade balance might not be an effective policy tool.

The rest of this paper is presented as follows: Section 2 introduces the stationary VAR representation of ECM, showing the elasticity and PPP approaches. In Section 3, the dynamic relationship between real exchange rate and trade balance in Korea is empirically analyzed. Section 4 concludes.

II. Stationary VAR Representation of ECM for Trade Balance and Real Exchange Rate

We first denote model (elasticity approach and PPP) variables $z_t=(y^*_t,$

p_t^*, y_t, p_t, ex_t, im_t, f_t) as the log-transformed variables for foreign output Y_t^*, foreign price level P_t^*, domestic output Y_t, domestic price level P_t, import IM_t, export EX_t, and nominal exchange rate F_t, respectively.[2]

Then, adopting the well-known non-stationarity of z_t, the l-dimensional, integrated to one, and demeaned/detrended VAR(p) process of z_t is given by

$$z_t = \Pi_1 z_{t-1} + \Pi_2 z_{t-2} + \cdots + \Pi_p z_{t-p} + \varepsilon_t, \tag{1}$$

or

$$\Delta z_t = \Phi z_{t-1} + \sum_{i=1}^{p-1} \Phi_i \Delta z_{t-i} + \varepsilon_t, \tag{2}$$

where $\bar{\Pi} = \sum_{i=1}^{p} \Pi_i$, $\Phi = \bar{\Pi} - I_\ell$, $\Phi_i = -(\Pi_{i+1} + \Pi_{i+2} + \cdots + \Pi_p)$ and ε_t is an $l \times 1$ vector of an independent and identically distributed disturbance term with finite variance $\Sigma > 0$. I_l denotes an l-dimensional identity matrix, and $\Delta z_t \equiv z_t - z_{t-1}$. Equation 1 is the most general linear dynamic model that reflects the dynamics of z_t in the elasticity and PPP approaches.

Further, we assume the cointegration of Equation 1 (*e.g.*, Johansen 1995) as $\Phi = \alpha\beta'$, where α and β are $l \times r$ matrices of the full-column rank r. Equation 2 can be written in ECM as

$$\Delta z_t = \alpha u_{t-1} + \sum_{i=1}^{p-1} \Phi_i \Delta z_{t-i} + \varepsilon_t \tag{3}$$

where $u_t = \beta' z_t$.

We assume the two theoretical long-run equilibria of the real exchange rate and trade balance in the external sector of the economy, which directly specify the cointegration vector β. First, PPP is given by $R_t \equiv F_t P_t^* / P_t = 1$, as extended from the law of one price, and second, the trade balance, represented by the real exchange rate, is given by $TB_t \equiv (R_t \times IM_t)/EX_t = 1$. These two equilibria can also be represented by their log transformation as follows:

$$r_t = f_t + p_t^* - p_t \tag{4}$$

[2] Domestic and foreign output variables are added to reflect their possible connection with import and export.

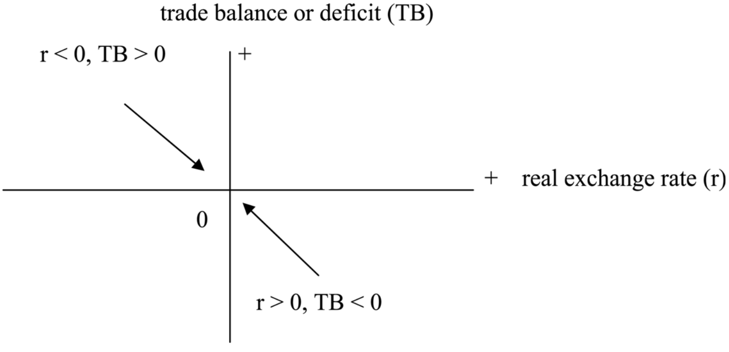

FIGURE 1
TYPICAL TRADE BALANCE–REAL EXCHANGE RATE ADJUSTMENT PROCESS

and

$$tb_t = r_t + im_t - ex_t \tag{5}$$

where $im_t \equiv im_t(y_t,\ r_t)$ and $ex_t \equiv ex_t(y^*_t,\ r_t)$.

Equations 4 and 5 can be regarded as cointegration relationships whenever both real exchange rate r_t and trade balance tb_t are stationary or $I(0)$ variables. These relationships represent the external equilibria of an economy: one is the financial sector and the other is the real sector. Figure 1 shows the joint adjustment process of the two variables.

In this case, the cointegration vectors are defined as $\beta_1 = (0,\ 1,\ 0,\ -1,\ -1,\ 1,\ 1)'$ and $\beta_2 = (0,\ 1,\ 0,\ -1,\ 0,\ 0,\ 1)'$. The normalized cointegration vectors of $(\beta'_1,\ \beta'_2)'$ can now be expressed as

$$\beta = (\gamma,\ I_2)$$

where

$$\gamma = \begin{pmatrix} 0 & 0 & 0 & 0 & -1 \\ 0 & 1 & 0 & -1 & 0 \end{pmatrix}.$$

The normalized cointegration errors are defined as $u_t = \beta' z_t = (r_t,\ tb_t)'$, where $tb_t = im_t - ex_t$.

ECM (Equation 3) obviously consists of all the stationary variables of

Δz_t and u_t. We are interested in the dynamic interaction between variables Δz_t and u_t. In this regard, we can apply the results of Pesaran and Shin (1996) or Hansen (2005). However, the VAR approach of Sims (1980) is sometimes more convenient for practical reasons. Thus, Kim (2012) showed that Equation 3 can be represented as a stationary VAR model when ECM is given.

To obtain a stationary VAR representation in this case, a non-singular lower triangular matrix is defined as

$$T \equiv \begin{pmatrix} I_5 & 0 \\ \gamma' & I_2 \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & -1 & 1 & 0 \\ 0 & 1 & 0 & -1 & 0 & 0 & 1 \end{pmatrix}.$$

The above matrix T transforms VAR variable z_t into variable w_t of $x_t = (y^*_t,\ p^*_t,\ y_t,\ p_t,\ im_t)$ and the cointegration error u_t as $Tz_t = (x_t',\ u_t')' \equiv w_t$, where x_t are explanatory variables in the cointegration relationships (Equations 4 and 5) of f_t and ex_t.

Kim (2012) subsequently showed that Equations 1 and 3 can be transformed into a VAR model of purely stationary variable $w_{\Delta t} = (\Delta x_t',\ u_t')'$ as[3]

$$w_{\Delta t} = \Psi_1 w_{\Delta t-1} + \Psi_2 w_{\Delta t-2} + \cdots + \Psi_p w_{\Delta t-p} + e_t \tag{6}$$

where Δx_{t-p} is not included in Equation 6 and $e_t = T\varepsilon_t$. Equation 6 is clearly equivalent to the original VAR model (Equation 1) or ECM (Equation 3) when ε_t has a Gaussian distribution.

Variable $w_{\Delta t-i} = (\Delta x_{t-i}',\ u_{t-i}')'$ for $i=0, 1, 2, \ldots, p$ is known if cointegration vector β (and, thus, $u_{t-i} = \beta' z_{t-i}$) is known. Therefore, we can consistently estimate coefficients Ψ_i in Equation 6 as $\hat{\Psi}_i$ with variables $w_{\Delta t-i}$

[3] Campbell and Shiller (1987, Equation 5) also used Equation 6 without referring to the VAR models (Equations 1 and 3). The optimal forecasting of u_{t+i} can be conducted using the usual recursive process in the VAR model, as presented by Lütkepohl (1991). Such approach is not possible in the research of Pesaran and Shin (1996) because their model is not in a VAR form.

using the ordinary least square or maximum likelihood (ML) estimation methods.

Thus, any standard dynamic analysis is possible using Equation 6. The traditional bivariate or multivariate Granger causality test can be conducted from Equation 6. For instance, if we are interested on whether Δx_t Granger causes u_t or not in a bivariate model, then we could test null hypothesis $H_0: \beta_1 = \beta_2 = \ldots = \beta_p = 0$ from following estimation equation:

$$u_t = c + \sum_{i=1}^{p} \alpha_i u_{t-i} + \sum_{j=1}^{p} \beta_j \Delta x_{t-j} + \xi_t.$$

Further, an i^{th} period ahead response of $w_{\Delta t}$ for a unit impulse of ε_t (that is, the error of Equation 1) can be computed from the following vector moving average representation of $w_{\Delta t}$ as

$$w_{\Delta t} = \Psi(L)^{-1} T\varepsilon_t = \sum\nolimits_{i=0}^{\infty} \Phi_i \varepsilon_{t-i} \tag{7}$$

which holds true for Equation 6 if $\Psi(L)$ is invertible, where L denotes a time-lag operator and $\Psi(L) = I - \Psi_1 L - \ldots - \Psi_p L^p$.

An ordering of the structural VAR model (Equation 1) is preserved in the transformed model (Equation 6), which is noteworthy for the identification of the structural VAR model.[4] To appreciate this relationship, we let $\varepsilon_t = P\xi_t$, where P is a lower triangular matrix and $E\xi_t\xi_t' = I_7$. Then, $e_t = P^* \xi_t$ from the definition, where $P^* = TP$ is a lower triangular matrix. Therefore, the ordering of Equation 1 is preserved in Equation 6.

If cointegration vector $\beta = (\gamma', I_r)$ is not known and only estimated as $\beta = (\hat{\gamma}, I_r)$ with super-consistency of $n^{1/2}(\hat{\gamma}' - \gamma) \to_p 0$ (Johansen 1995), where n is a sample number, then $w_{\Delta t-i}$ must be replaced by $\hat{w}_{\Delta t-i} = (\Delta x_{t-i}', \hat{u}_{t-i}')'$, where $\hat{u}_{t-i} = \hat{\beta}' z_{t-i}$. In this case, standard dynamic analyses can still be conducted and inferences can be drawn because $\hat{\beta}$ can be considered as a known β because of its rapid convergence or super consistency.

[4] This result implies that the cointegration explanatory variables x_t are in front of the cointegration dependent variables (f_t and ex_t in this case) in the ordering. This ordering may be natural based on an economic theory. For instance, a relative price determines a conformable exchange rate according to the PPP theory. However, we do not need to impose any restriction on the ordering of variables by themselves for x_t (or u_t) to obtain this result.

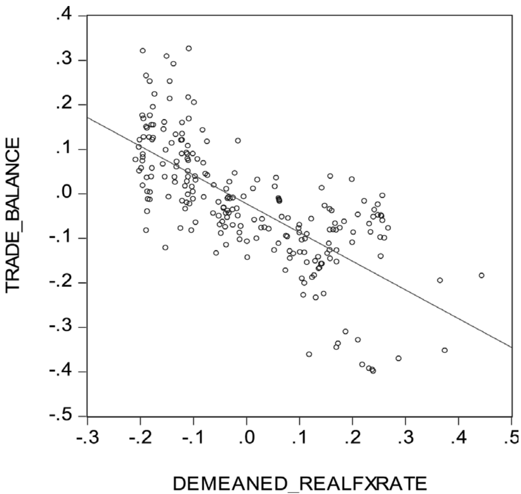

FIGURE 2
TRADE BALANCE–REAL EXCHANGE RATE
EMPIRICAL RELATIONSHIP

III. Empirical Application to Korea–U.S. Monthly Data

We applied the suggested method to the Korea–U.S. data set with a monthly frequency. The data were drawn from the economic statistics system of the Bank of Korea. The industrial production index was used as a proxy for the output variable. The producer price index (not the consumer price index) for Korea or the U.S. was used as the price level to minimize the weight of non-tradable goods. The industrial production index was seasonally adjusted to eliminate potential seasonality. The exchange rate used is the monthly average of the won/dollar closing price, and the export/import values are based on FOB prices. All variables are transformed into their natural logarithm. The data spanned from March 1990 to June 2008, except for the recent global financial crisis. Thus, two periods are compared: before the Asian financial crisis (March 1990-September 1997) and the entire period (March 1990-June 2008) to identify a possible structural change in Korean economy, if any exists.

Figure 2 shows the relationship between the trade balance (deficit) and the demeaned real exchange rate for the entire period, clearly indicating that an increase in real exchange rate results in a decrease in trade deficit, as theoretically expected and shown in Figure 1.

TABLE 1

(a) Results of the Johansen Cointegration Test

	Before Asian crisis		Whole period	
	Trace	Max-eigen	Trace	Max-eigen
Expected number of cointegrations[1]	2	0	2	1

Note: 1) 5% level basis.

(b) Estimated Cointegration Vector[2]

	Before Asian crisis		Whole period	
	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\beta}_1$	$\hat{\beta}_2$
y^*_t	-42.20 (9.051)	-5.707 (2.407)	-0.014 (0.648)	-0.702 (0.351)
p^*_t	7.689 (7.592)	0.589 (2.019)	0.462 (0.671)	**0.365 (0.364)**
y_t	6.329 (2.289)	1.689 (0.608)	-0.585 (0.179)	-0.473 (0.097)
p_t	47.40 (10.50)	11.91 (2.793)	3.173 (0.631)	**-2.551 (0.342)**
ex_t	-9.723 (1.600)	-2.192 (0.425)	**-1.410 (0.139)**	0.970 (0.075)
im_t	1	0	1	0
f_t	0	1	0	1

Note: 2) Standard errors are captured in parentheses.

A. Estimation of long-run Equilibrium and Short-run Adjustment

First, according to the Schwarz/Akaike information criterion, we let the order of VAR model (Equation 1) be equal to three for the two selected periods. The results of the standard unit root tests did not reject the null hypothesis of a unit root for the model variables. Thus, we conducted the Johansen cointegration test and found that the trace test indicated two cointegrating relationships at the 0.05 level for both the period before the Asian crisis and the entire period (Table 1(a)). Further the log-likelihood ratio test for the joint theoretical cointegration vectors $\beta_1=(0, 1, 0, -1, -1, 1, 1)'$ and $\beta_2=(0, 1, 0, -1, 0, 0, 1)'$ did not reject the null with a 5% significance level. This result did not contradict the theoretical expectation that the trade balance and real exchange rate are stationary or $I(0)$.

The cointegration vectors were estimated using the full information ML suggested by Johansen (1995) (Table 1(b)). The estimated cointegration coefficients using the whole period data have the same signs as the theoretical ones (-1 for ex_t and 1 and -1 for p^*_t and p_t, respectively).

TABLE 2
ESTIMATION RESULTS OF THE SHORT-RUN DYNAMICS OF TRADE BALANCE

Dependent variable	tb_t		$\hat{\beta}_1' z_t$	
	before Asian crisis	whole period	before Asian crisis	whole period
Const.	0.775(1.109)	**1.304(3.272)****	15.33(1.327)	**-14.00(-2.360)****
tb_{t-1}	**0.358(3.035)****	**0.283(4.087)****	**0.391(2.398)****	**0.273(3.364)****
tb_{t-2}	**0.220(1.811)***	**0.150(2.145)*****	**0.439(2.572)****	**0.159(1.927)***
tb_{t-3}	0.069(0.553)	**0.322(4.484)****	0.070(0.395)	**0.466(5.362)****
r_{t-1}	0.149(0.406)	**-0.572(-2.640)****	2.079(0.535)	**5.916(2.645)****
r_{t-2}	-0.192(-0.328)	0.117(0.331)	0.957(0.161)	**-8.679(-2.362)****
r_{t-3}	-0.059(-0.158)	0.277(1.220)	-2.921(-.804)	2.767(1.196)
Δy^*_{t-1}	-0.246(-0.207)	**-1.644(-2.259)****	24.19(0.920)	0.456(0.030)
Δy^*_{t-2}	0.425(0.359)	0.272(0.371)	23.35(0.911)	**-48.07(-3.045)****
Δp^*_{t-1}	-0.703(-0.649)	0.700(0.813)	5.644(0.542)	-9.896(-1.115)
Δp^*_{t-2}	1.189(1.065)	-0.023(-0.026)	2.169(0.210)	0.259(0.028)
Δy_{t-1}	0.027(0.247)	**-0.284(-3.005)****	-3.810(-.532)	**-13.15(-3.324)****
Δy_{t-2}	-0.003(-0.030)	-0.074(-0.836)	-7.191(-0.124)	3.517(0.855)
Δp_{t-1}	**3.652(2.377)****	**2.023(2.000)****	4.028(0.074)	-11.38(-0.324)
Δp_{t-2}	-1.679(-1.047)	**-3.022(-3.155)****	5.434(0.110)	31.37(0.901)
R^2	0.463	0.745	0.865	0.738
D.W.	1.997	1.985	1.933	1.999

Note: 1) ** and * denote the 5% and 10% levels of significance, respectively.
2) t-values are captured in parentheses.

However, such coincidence does not occur in the estimation using the data before the Asian crisis. We suspect that these differences might be related to the incomplete or managed floating exchange rate regime of Korea before the Asian crisis, which hindered the market mechanism toward PPP.

We then estimated Equation 6 to analyze the short-run adjustment of the real exchange rate and trade balance toward equilibria using the theoretical and estimated cointegration vectors. Then, we conducted the F-test using estimated Equation 6. The results are shown in Tables 2 and 3, and the main findings are summarized as follows:

First, the trade balance was significantly affected by the (once lagged) real exchange rate, as predicted by the elasticity approach when the data for the entire period were used. This result confirmed the findings of Goldstein and Kahn (1985), Rose and Yellen (1989), Moura and Silva (2005), and Hsing (2008). However, the response of the trade balance to the shock of an element (nominal exchange rate and prices) that com-

TABLE 3
ESTIMATION RESULTS OF THE SHORT-RUN DYNAMICS OF REAL EXCHANGE RATE

Dependent variable	r_t		$\hat{\beta}_2' z_t$	
	before Asian crisis	whole period	before Asian crisis	whole period
Const.	0.023(0.099)	-0.007(-0.050)	3.080(1.410)	-1.106(-1.094)
tb_{t-1}	-0.017(-0.439)	0.007(0.297)	-0.037(-1.231)	**-0.046(-3.327)****
tb_{t-2}	**0.090(2.172)****	0.016(0.650)	0.028(0.870)	**0.050(3.557)****
tb_{t-3}	-0.009(-0.214)	0.010(0.411)	-0.006(-0.194)	-0.012(-0.850)
r_{t-1}	**1.302(10.33)****	**1.475(18.85)****	**2.375(3.232)****	**2.898(7.610)****
r_{t-2}	**-0.365(-1.823)***	**-0.627(-4.888)****	-1.120(-0.998)	**-2.086(-3.334)****
r_{t-3}	0.060(0.473)	**0.153(1.867)***	-0.256(-0.372)	0.186(0.472)
Δy^*_{t-1}	-0.554(-1.364)	0.331(1.262)	**13.49(2.716)****	**12.47(4.931)****
Δy^*_{t-2}	-0.669(-1.649)	-0.087(-0.332)	0.756(0.156)	-1.302(-0.484)
Δp^*_{t-1}	**-0.679(-1.829)***	**-0.576(-1.855)***	-0.245(-0.124)	1.780(1.178)
Δp^*_{t-2}	0.564(1.472)	0.818(2.603)**	1.992(1.021)	**4.176(2.731)****
Δy_{t-1}	**-0.082(-2.209)****	-0.059(-1.747)	**-3.164(-2.337)****	**-4.097(-6.078)****
Δy_{t-2}	**-0.112(-2.994)****	-0.005(-0.174)	-1.269(-1.048)	-0.057(-0.082)
Δp_{t-1}	0.148(0.282)	-0.216(-0.594)	-15.89(-1.551)	**-23.32(-3.901)****
Δp_{t-2}	-0.407(-0.740)	**-0.811(-2.347)****	6.902(0.744)	**5.556(0.936)****
R^2	0.964	0.972	0.974	0.995
D.W.	2.020	1.945	2.017	2.037

Note: ** and * denote the 5% and 10% levels of significance, respectively.

posed the real exchange rate is also interesting. Thus, this subject will be discussed later in the impulse-response function (IRF) estimation section.

Second, the trade balance was significantly affected by the macro-variables, such as income or prices, in estimation cases that used the entire-period data. However, such results were not observed in the estimation using the data before the Asian crisis. We suspect that this difference by period might be related to the ongoing change in the trade product quality in Korea. Before the Asian crisis, Korean trade goods were mainly concentrated on light-industry products, including textiles and footwear, which typically have low quality. We expected that these products have low elasticity with respect to income or price changes. However, after the Asian financial crisis, Korean trade goods have been upgraded to heavy-industry products, including machineries and equipment and electronic products. These products have relatively high elasticity relative to income or price changes, which well explained the estimation result.

Third, the real exchange rate estimation for the period before the Asian crisis showed that the income and trade balance were statistically significant explanatory variables. The same results were not observed in the estimation using the whole-period data. We suspect that this result occurred because the PPP dynamics is more dominant after the Asian crisis than before the crisis because a free-floating foreign exchange system has been adopted in Korea after the Asian crisis. Under the managed floating system before the crisis, substantive government interventions in the foreign exchange market to improve trade balance or industrial growth (as a policy target variable) may have been conducted. However, after the Asian crisis, direct market mechanism based on relative prices has begun to take effect, which may have influenced the estimation results.

B. Impulse Response and Variance Decomposition Results

IRF and variance decomposition were conducted using the VAR model (Equation 6). Here, we set the identification order of Equation 1 as y^*_t, p^*_t, y_t, p_t, ex_t, im_t, and f_t. This ordering appears reasonable due to the following reasons: 1) foreign aspect precedes the domestic one because Korea is a small open economy; 2) output precedes the price because of price rigidity; 3) real economic activities determine the imports and exports; and 4) all these variables finally determine the exchange rate. The strength of this IRF approach in the VAR model was indicated by its ability to enable us decompose the shock of real exchange rate or trade balance into its constituent sub-shocks (nominal exchange rate, prices, import, and export).

The estimated IRFs are shown in the Appendix. The key findings of the IRF analysis and the variance decomposition are as follows:

First, we confirmed the findings of Cheung *et al.* (2004) that the nominal exchange rate adjustment, not the price adjustment, is the key engine that governs the speed of PPP convergence, and the nominal exchange rates are found to converge much more slowly than prices. The response of the real exchange rate to the nominal exchange rate shock has long-term persistence, whereas domestic and foreign prices have relatively short-term persistence. The variance decompositions also showed similar results. For instance, nominal exchange exhibited a dominant part in the real exchange rate variance.

This finding is very important in international or open macro-economic theory because it challenges conventional price-stickiness explanations and raises new questions/puzzles in modeling of PPP disequilibrium dynamics. Among these issues are the following: why do nominal exchange rates converge so slowly (Engel and Morley 2001)? Why are the convergence rates of prices and nominal exchange rates different? Can heterogeneous convergence speeds be consistent in general equilibrium (Cheung *et al.* 2004)? We should note that the typical models of PPP disequilibrium adjustment assume that prices and nominal exchange rates will both converge to steady state at the same rate. The empirical evidences are not consistent with the theoretical expectations, that is, "The differing speeds of convergence thus constitute a special puzzle that calls for new explanations (Cheung *et al.* 2004)."

However, the exchange rate shock dissipates very quickly when the estimated (not theoretical) cointegration error is used. Thus, a question arises as to why this difference between the theoretical and estimated values occurs. To explain it theoretically, we define a generalized cointegration relationship of foreign exchange as[5]

$$f_t = \lambda_1 p_t^* + \lambda_2 p_t + \lambda_3 x_t + \xi_t$$

where x_t is the other variable that determines the exchange rate and ξ_t is stationary variable. PPP implies that $\lambda_1=1$, $\lambda_2=-1$, $\lambda_3=0$. However, typical causes, like non-trade goods, incomplete competition, tariff, and transaction costs hindered the implementation of PPP; thus, the IRF for the real exchange rate can be written as

$$\frac{\partial r_{t+j}}{\partial \varepsilon_{it}} = (\lambda_1 + 1)\frac{p_{t+j}^*}{\partial \varepsilon_{it}} + (\lambda_2 - 1)\frac{p_{t+j}}{\partial \varepsilon_{it}} + \lambda_3 \frac{x_{t+j}}{\partial \varepsilon_{it}} + \frac{\xi_{t+j}}{\partial \varepsilon_{it}}$$

because we can express $r_t=(\lambda_1+1)p_t^*+(\lambda_2-1)p_t+\lambda_3 x_t+\xi_t$. When PPP does not hold, the long-persistence variables p_t^*, p_t, x_t lengthens the IRF life. However, if λ_1, λ_2, and λ_3 are correctly estimated, then IRF becomes approximately

$$\frac{\partial r_{t+j}}{\partial \varepsilon_{it}} = \frac{\xi_{t+j}}{\partial \varepsilon_{it}}$$

which has a short persistence.

Second, the nominal exchange shock slightly affected the trade balance

[5] See Liu (1992) for an example using a generalized form of PPP.

regardless of the data periods.[6] This result is interesting because the U.S. has been concerned with potential exchange rate manipulation or intervention in East Asian countries for their trade surplus (see Krugman and Baldwin (1987) for this issue). This condition implies that, at least, the change in the nominal exchange rate is not quite effective if it is focused on the improvement of trade surplus based on the estimation result. However, prices, exports, and imports significantly affect the trade balance when the data for the whole period were used for the estimation. For instance, the trade deficit sharply increased after an import shock. Therefore, we conclude that the industrial/commercial approach (*e.g.*, imposing a levy on unnecessary imports) and not the financial approach (*e.g.*, foreign exchange market intervention) is required to attain a sound trade balance for Korea. This result implies that foreign exchange rate intervention is not quite effective in improving the trade balance in Korea[7] even if the real exchange rate could affect the trade balance.

IV. Conclusion

This paper has analyzed the trade balance and real exchange rate dynamics based on the elasticity and cointegration approaches. In this study, a stationary VAR model with cointegration error transformed from ECM in Kim (2012) was employed. Trade balance and PPP were jointly considered as the two long-run cointegration relationships that represent external economy equilibria. The model was applied in the dynamic analyses of Korea's trade balance using monthly data after 1990, where the model variables were selected from the elasticity approach. Based on estimation, we first confirmed the finding of Cheung *et al.* (2004). The nominal exchange rate adjustment (not the price adjustment) is the key engine that governs the speed of PPP convergence, and nominal exchange rates are found to converge much more slowly than prices. This finding is very important in international or open macro-economic theory because it challenges conventional the price-stickiness theory and raises new questions in modeling of PPP disequilibrium dynamics, essentially

[6] However, we have to interpret cautiously the IRF results for the exchange rate (or price shocks) that, in general, these do not have much structural/direct implications to the policy (with the rare exception of the exchange rate intervention policy). The author is indebted to the co-editor for this interpretation of IRF.

[7] However, this conclusion does not imply that foreign exchange rate intervention is completely useless because it still has the potential role of achieving foreign exchange stability.

driven by nominal exchange rate. The nominal exchange shock did not significantly affect trade balance, whereas the price shocks did. Therefore, nominal exchange rate manipulation through intervention to improve trade balance might not be an effective policy tool.

Additional work on this topic is necessary. First, future research is required to extend the current linear model to a non-linear one, as in Wu and Chen (2001) and Granger and Swanson (1997). Second, the results of the present study, which is limited to Korean data, should be verified using data from other countries similarly affected by the Asian financial crisis and adopted the free-floating exchange rate system.

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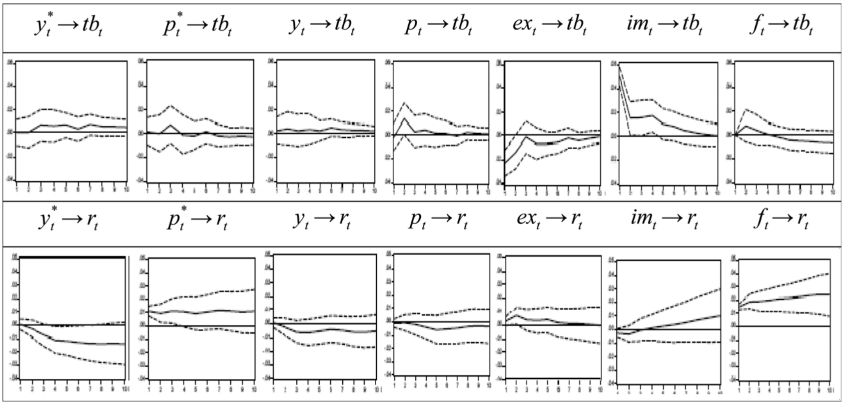
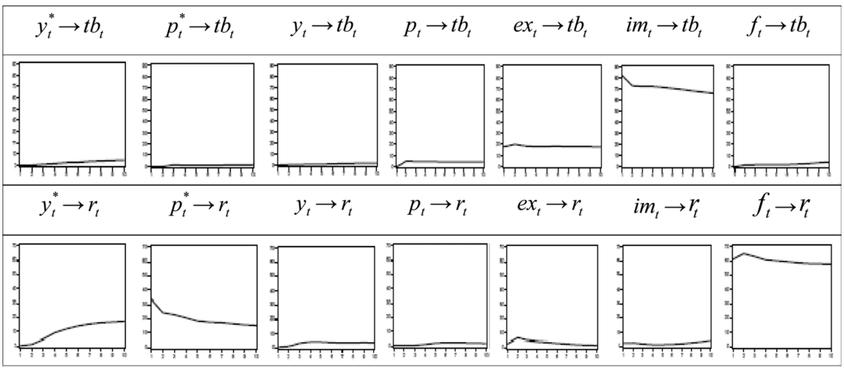
Appendix. Impulse Response and Variance Decomposition

A. Using Theoretical Cointegration Vector (Before the Asian Crisis)

a. Impulse Response

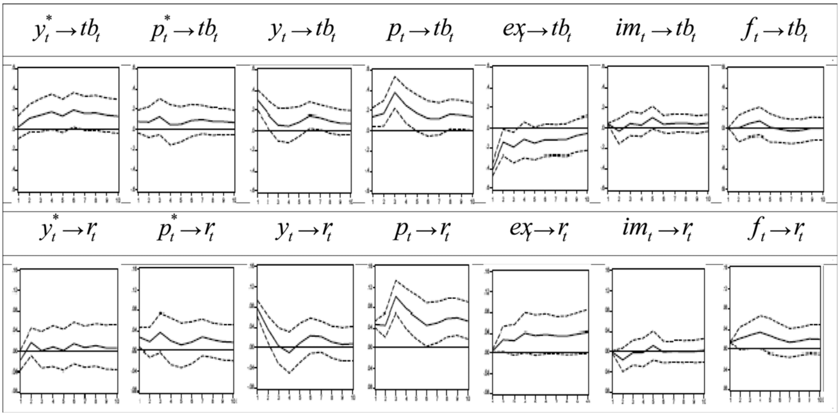


b. Variance Decomposition

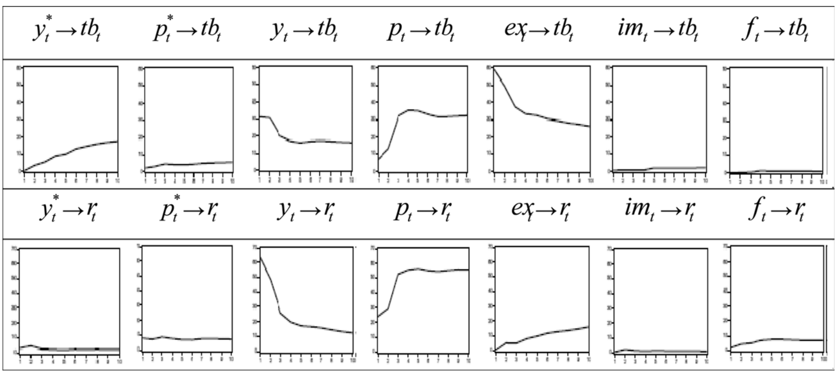


B. Using Estimated Cointegration Vector (Before the Asian Crisis)

a. Impulse Response

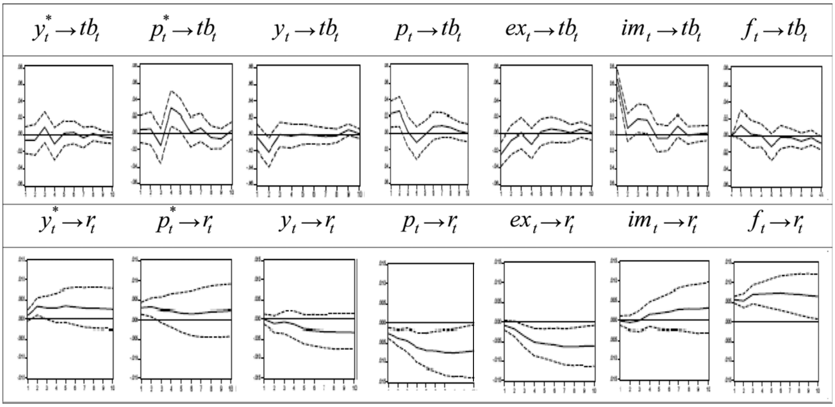


b. Variance Decomposition

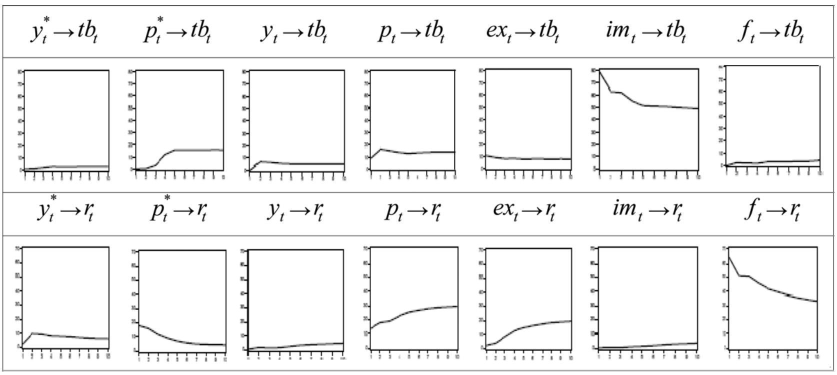


C. Using Theoretical Cointegration Vector (Whole Period)

a. Impulse Response

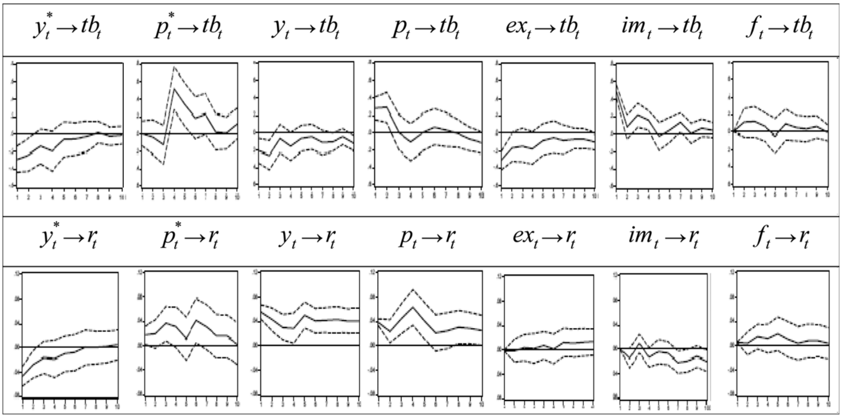


b. Variance Decomposition

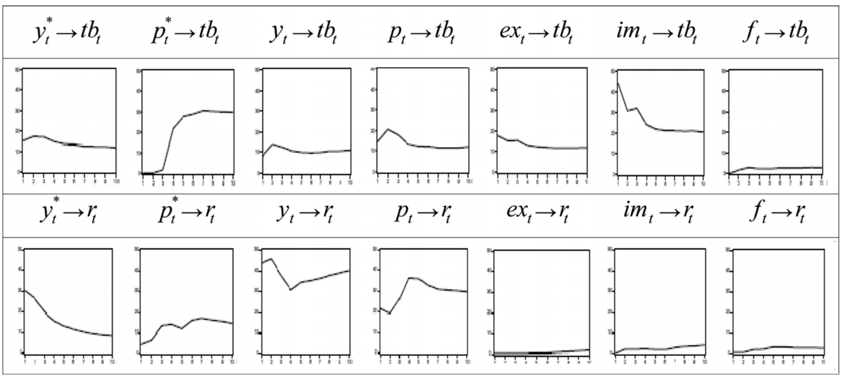


D. Using Estimated Cointegration Vector (Whole Period)

a. Impulse Response



b. Variance Decomposition



References

Campbell, J. Y., and Shiller, R. J. "Cointegration and Tests of Present Value Models." *Journal of Political Economy* 95 (No. 5 1987): 1062-88.

Cheung, Y-W, Lai, K. S., and Bergman, M. "Dissecting the PPP Puzzle: the Unconventional Roles of Nominal Exchange Rate and Price Adjustments." *Journal of International Economics* 64 (No. 1 2004): 135-50.

Engel, C., and Morley, J. C. The Adjustment of Prices and the Adjustment of the Exchange Rate. NBER Working Papers No. 8550, National Bureau of Economic Research, 2001.

Goldstein, M., and Khan, M. S. "Income and Price Effects in Foreign Trade." In R. W. Jones and P. B. Kenen (eds.), *Handbook of International Economics.* Volume II, Amsterdam: North-Holland, pp. 979-1040, 1985.

Granger, C. W. J., and Swanson, N. R. "An Introduction to Stochastic Unit Root Processes." *Journal of Econometrics* 80 (No. 1 1997): 35-62.

Hansen, P. R. "Granger's Representation Theorem: A Closed-Form Expression for I(1) Processes." *Econometrics Journal* 8 (No. 1 2005): 23-38.

Hsing, Y. "Effects of Crude Oil Prices and Macroeconomic Conditions on Output Growth in Mexico." *International Journal of Trade and Global Markets* 1 (No. 4 2008): 409-18.

Johansen, S. *Likelihood-Based Inference in Cointegrated Vector Autoregressive Models.* New York: Oxford University Press, 1995.

Kim, J. Y. "Measuring the Length of Period for the Long-Run Equilibrium in a Cointegration Relation." *Seoul Journal of Economics* 16 (No. 1 2003): 71-80.

Kim, Y-Y. "Stationary Vector Autoregressive Representation of Error Correction Models." *Theoretical Economics Letters* 2 (No. 2 2012): 152-6.

Kim, Y-Y, and Park, Joon Y. "Testing Purchasing Power Parity in Transformed ECM with Nonstationary Disequilibrium Error." *Economic Papers* 11 (No. 2 2008): 75-95.

Krugman, P. R., and Baldwin, R. E. "The Persistence of the U.S. Trade Deficit." *Brookings Papers on Economic Activity* 18 (No. 1 1987): 1-56.

Liu, P. "Purchasing Power Parity in Latin America: A Co-integration Analysis." *Weltwirtschaftliches Archiv* 128 (No. 4 1992): 662-80.

Lütkepohl, H. *Introduction to Multiple Time Series Analysis.* New York: Springer Verlag, 1991.

Moura, G., and Silva, S. D. "Is There a Brazilian J-Curve?" *Economics Bulletin* 6 (No. 10 2005): 1-17.

Pesaran, M. H., and Shin, Y. "Cointegration and Speed of Convergence to Equilibrium." *Journal of Econometrics* 71 (No 1. 1996): 117-43.

________. "Generalized Impulse Response Analysis in Linear Multivariate Models." *Economic Letters* 58 (No. 1 1998): 17-29.

Rose, A., and Yellen, J. "Is There a J-Curve?" *Journal of Monetary*

Economics 24 (No. 1 1989): 53-68.

Sims, C. A. "Macroeconomics and Reality." *Econometrica* 48 (No. 1 1980): 1-48.

Wu, J. L., and Chen, S. L. "Nominal Exchange-Rate Prediction: Evidence from a Nonlinear Approach." *Journal of International Money and Finance* 20 (No. 4 2001): 521-32.