Revisiting the Marshall-Lerner Condition under Processing Trade– Empirical Evidence from China*

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Abstract

With the real exchange rate elasticity of processing net exports being positively related to the processing trade intensity, the modified Marshall-Lerner condition states that a real exchange rate appreciation tends to increase rather than reduce net exports, as long as the composite export elasticity with respect to import via the real exchange rate is sufficiently large. The estimated cointegration relationship of China's data suggests a robust channel of processing trade through which processing exports increase more than processing imports in response to a real appreciation of Chinese currency vis-à-vis the U.S. dollar.

I. Introduction

There are probably few other ever-lasting issues on today's international money more "fashionable" and attractive than the following: Will RMB appreciation reduce China's net exports (RMB stands for Renminbi, the official currency in China)? Despite the lasting discussion in academia and the policy practitioners' endeavor in pushing RMB appreciation, the answer to the question seems to be neither obvious nor unambiguous.[1] The traditional elasticity approach appeals to the relative price effect, such as the Marshall-Lerner condition, [2] and suggests that net exports fall as the domestic currency appreciates in real terms. Nevertheless, there are some studies, *albeit* not the main stream, that have presented diversified perspectives toward the issue.

A more broad economics literature in this regard, suggests that the income elasticity of imports is much greater than that of exports, which could help explain why the income effect from appreciation favors an increase rather than a decrease in net exports (Houthakker and

[1] For some recent studies that address the issue, see Frankel (2005), McKinnon (2006), Cheung *et al* (2009), Qin and He (2010), among others.
[2] The Marshall-Lerner condition says that a real exchange rate appreciation reduces net exports provided the sum of export and import elasticities exceeds unity. For its introduction, see Dornbusch (1980).

Magee, 1969; and Baily and Lawrence, 2006). McKinnon (2006), however, explains why the relative price effect on trade imbalances as predicted by the traditional elasticity approach could be offset by an appreciation. McKinnon and Schnabl (2008) argues that appreciation raises the cost of production so that domestic investment would fall; and therefore, the domestic aggregate demand absorbs less in the goods market than otherwise, then *ceteris paribus,* net exports could increase instead. In particular, McKinnon (2005) notes the phenomenon of conflicted virtue in which high-saving countries have to own a huge amount of foreign currency-denominated claims; along this line, Qiao (2007) further indicates that RMB appreciation tends to produce a negative wealth effect that reduces domestic expenditures on imports as well as domestically-made goods, which could mitigate the relative price effect on exports.

Although this paper shares the unorthodox view on the exchange rate elasticity of net export, it is the existence of processing trade, as argued in this study, that changes our conventional understanding of the issue: significant dependence of exports on imports causes net exports to increase rather than decrease as a result of RMB appreciation. Processing trade, a major engine for China's extraordinary economic growth in the past, in general refers to the business activity of importing all or part of the raw or auxiliary materials from abroad and re-exporting the finished products after processing or assembly. High import content of export becomes characteristic of processing trade, as export determines import and import is mainly for export.

Indeed, two recent studies investigate processing trade from a trade perspective (Koopman *et al*., 2008; Aziz and Li, 2007), but it seems that no one to date has attempted to examine the dynamic impact of processing trade on the orthodox pattern that net exports fall as the real exchange rate rises. How does the presence of significant processing trade change the pattern for net exports to respond to the nominal and real exchange rates? And how effective would it be to push a processing-trade dependent economy to adjust its nominal exchange rate in order to correct trade imbalances in a direction predicted by the orthodox international economics doctrine? This paper starts with an analysis that incorporates processing trade but modifies the Marshall-Lerner condition accordingly, and then, using the data of China's processing trade, further tests the significance of processing trade and the modified Marshall-Lerner condition by estimating the trade elasticities in a vector-error-correction (VEC) model.

II. A Modified Marshall-Lerner Condition under Processing Trade

Define the nominal exchange rate as the units of foreign currency per unit of the domestic currency. The well-known Marshall-Lerner condition states that a real exchange rate appreciation (terms-of-trade improvement, i.e., a rise in relative price of exports) will reduce net exports as long as the sum of the absolute values of the real exchange rate elasticity of exports and imports is greater than one in the case of initial balanced trade, and in the case of unbalanced trade, the sum of the absolute value of the real exchange rate elasticity of exports and the absolute value of the real exchange rate elasticity of imports multiplied by the ratio of imports to exports is greater than one. The scenario analyzed by the Marshall-Lerner condition involves only conventional exports and imports in which the import content of export is disregarded. However, to deal with processing trade with large import content of export, there is a need to take into account of the dependence of exports on imports.

Following the conventional notations, e is the nominal exchange rate expressed as the dollar price of the processing-trade country's currency (say, RMB) so that e represents units of the dollar per yuan. The real exchange rate ε equals eP/P^*, where P is the price of the processing-trade country's exportables, and P* is the price of the processing-trade country's importables. Since the processing-trade country's export demand are equivalent to its trade partner's import demand in the case of bilateral trade, the processing-trade country's export function is denoted by M*(ε, M(ε)) whereas its import function is represented by M(ε). Now, consider the logarithm of the export-to-import ratio as the proxy for the processing-trade country's trade balance (or net exports):

$$log\left(\frac{\varepsilon M^*}{M}\right) = log\left[\varepsilon M^*\left(\varepsilon, M(\varepsilon)\right)\right] - log[M(\varepsilon)] \quad (1)$$

where export depends negatively on the real exchange rate but positively on imports, and import in turn is an increasing function of the real exchange rate. The expression (1), as a functional transformation, is positively related to net export per se; but the advantage of taking logarithm of the export-import ratio provides an alternative but equivalent way to examine changes in net export while avoiding the measurement sensitivity to whether it is in terms of the nominal or real terms.

Differentiating (1) with respect to the real exchange rate produces the modified Marshall-Lerner condition:

$$\frac{\partial log\left(\frac{\varepsilon M^*}{M}\right)}{\partial \varepsilon} = \frac{1}{\varepsilon} \cdot (1 + \alpha\beta + \alpha^* - \alpha) \quad (2)$$

where α* is the export elasticity with respect to the real exchange rate, α is the import elasticity with respect to the real exchange rate, and β is the export elasticity with respect to import. A positive value for the RHS of (2) suggests that a real appreciation increases rather than reduces net export, and vice versa. The condition in (2) deviates from the Marshall-Lerner condition by the processing-trade term αβ, the composite export elasticity with respect to import via the real exchange rate, which increases the possibility that increased net exports could follow a real appreciation rather than a real depreciation. Indeed, the import content of processed exports and the export dependence on import provides an additional channel for the real exchange rate to influence trade balance: import is not only the factor that reduces net export but also plays an intermediary role in increasing exports. With the real exchange rate elasticity of processing net exports being positively related to the processing trade intensity, the modified Marshall-Lerner condition states that a real exchange rate appreciation tends to increase rather than reduce net exports, as long as the composite export elasticity with respect to import via the real exchange rate is sufficiently large. The estimated cointegration relationship of China's data suggests a robust channel of processing trade through which processing exports increase more than processing imports in response to a real appreciation of Chinese currency.

Furthermore, unlike the Marshall-Lerner condition, the condition (2) is not dependent on the size of import relative to export due to the use of proxy measure for trade balance. Although taking logarithm of the export-to-import ratio implies that trade is initially in surplus, trade deficit can be tackled by taking logarithm of the import-to-export ratio; that is, the general validity of the condition (2) does not depend on the initial trade balance, either trade surplus or trade deficit. Therefore, in determining the effect of real exchange-rate movement on net exports, what really matters is the magnitude of the sum of the export demand elasticity (α^*) and import demand elasticity (α) with respect to the real exchange rate relative to the intermediate export demand elasticity via import ($\alpha\beta$) plus one.

III. Estimation Approach

In order to apply the condition (2) to a real-world case, the parameter values of the elasticities need to be determined by appropriate estimates. The estimation methodology used in this paper concerns the estimation of two co-integration relationships within the setting of vector-error correction model. The data used in this paper are from the China Economic Information Network and CEIC databases. The export series and import series are derived from the accumulated monthly figures of processing trade by differencing, and the unit of measurement is adjusted from thousand dollars to million dollars, and the real exchange rate is the ratio of the dollar price of Chinese goods to the U.S. goods prices. The four series used in the paper are the value of China's export (LEXPPT), the value of China's import (LIMPPT), the real dollar/RMB exchange rate (LREALUSRMB), and real GDP (LGGDP), with all the variables in their logarithm.

The pre-condition for the validity of cointegration estimation and vector-error correction analysis requires that the investigated series are nonstationary in their levels (I(1) processes) but stationary in the first differences (I(0) processes). The unit root tests, the Augmented Dicky-Fuller (ADF) test and Phillips-Perron (PP) test, are used to check the stationarity of the above four time series and detect the existence of unit roots in the series. With the results from the unit root tests, the Johansen cointegration test (the λ_{trace} statistic test and λ_{max} statistic test) is run to detect any long-run equilibrium (i.e., cointegration) relationship among the non-stationary series (Johansen, 1991, 1995). Cointegration exists among some non-stationary time series if a linear combination of the non-stationary series is stationary. The cointegration model can be used to detect the long run Granger causality relationship by testing whether the speed-of-adjustment coefficient for the disequilibrium error term is significantly different from zero. For example, if X_k does not Granger cause X_h, X_h is said to be weakly exogenous for the cointegrating vector; alternatively, X_h does not react to disequilibrium errors, that is, the disequilibrium error and the cointegrating vector do not contain the information content helpful in predicting X_h.

Once the evidence for cointegration can be established, the rest of the work concerns a maximum likelihood estimation of a fully specified VEC model in which the short-run behavior of investigated variables are tied to their long-run values through an error-correction process. The estimated VEC model can identify the short-run Granger causality relationships in a pairwise way by testing at first whether an endogenous variable can be individually treated as exogenous and then whether all other lagged endogenous variables can be collectively treated as exogenous. The estimated VEC model can also trace short-term dynamics among exports, imports, and real exchange rates. Finally, as shown by Lütkepohl and Reimers (1992), innovation accounting can be used in a VEC model to obtain the useful information concerning interactions among the interested variables. The impulse response function is used to generate a forecast error variance decomposition, which measures the proportion of the movements in a variable caused by its "own" shocks versus the shocks to other variables; the larger the proportion of the forecast error variance of a variable is explained by other variables at all forecast horizons, the more endogenous the variable tends to be.

The one- and three- period lag for the VAR portion is chosen for the VEC model with the co-integration equation for processing export and the VEC model with the co-integration equation for processing import, respectively, based on the Akaike (AIC) criterion. Formally, the VEC model with the co-integration equation for processing export can be written as the system with three equations (3) through (5)

$$\Delta LEXPPT_t = a_{10} + \alpha_1(LEXPPT_{t-1} - \beta_0 - \beta_1 LIMPPT_{t-1} - \beta_2 LREALUSRMB_{t-1}) + a_{11}\Delta LEXPPT_{t-1} + a_{12}\Delta LIMPPT_{t-1} + a_{13}\Delta LREALUSRMB_{t-1} + LGGDP + \varepsilon_{1t} \quad (3)$$

$$\Delta LIMPPT_t = a_{20} + \alpha_2(LEXPPT_{t-1} - \beta_0 - \beta_1 LIMPPT_{t-1} - \beta_2 LREALUSRMB_{t-1}) +$$
$$a_{21}\Delta LEXPPT_{t-1} + a_{22}\Delta LIMPPT_{t-1} + a_{23}\Delta LREALUSRMB_{t-1} + LGGDP + \varepsilon_{2t} \quad (4)$$

$$\Delta LREALUSR = a_{30} + \alpha_3(LEXPPT_{t-1} - \beta_0 - \beta_1 LIMPPT_{t-1} - \beta_2 LREALUSRMB_{t-1}) +$$
$$a_{31}\Delta LEXPPT_{t-1} + a_{32}\Delta LIMPPT_{t-1} + a_{33}\Delta LREALUSRMB_{t-1} + LGGDP + \varepsilon_{3t} \quad (5)$$

where βs are the long-run coefficient in the co-integration relationship for the export function, αs are the adjustment coefficient to disequilibrium, and a_{jk}(i) is the i-period lagged response of the jth variable to the change in the kth variable (*j*, *k* = LEXPPT, LIMPPT, LREALUSRMB).

The second VEC model is the one with the co-integration equation for processing import, with the two equations (6) and (7):

$$\Delta LIMPPT_t = b_{10} + \gamma_1(LIMPPT_{t-1} - \delta_0 - \delta_1 LREALUSRMB_{t-1}) +$$
$$\sum_{i=1}^{3} b_{11}(i)\Delta LIMPPT_{t-i} + \sum_{i=1}^{3} b_{12}(i)\,\Delta LREALUSRMB_{t-i} + LGGDP + \epsilon_{1t} \quad (6)$$

$$\Delta LREALUSRMB_t = b_{20} + \gamma_2(LIMPPT_{t-1} - \delta_0 - \delta_1 LREALUSRMB_{t-1}) +$$
$$\sum_{i=1}^{3} b_{21}(i)\Delta LIMPPT_{t-i} + \sum_{i=1}^{3} b_{22}(i)\,\Delta LREALUSRMB_{t-i} + LGGDP + \epsilon_{2t} \quad (7)$$

where δs are the long-run coefficient estimates in the co-integration relationship for the import function, γs are the coefficient estimates of the speed of adjustment to disequilibrium, and a_{jk}(i) is the i-period lagged response of the jth variable to the change in the kth variable (*j*, *k* = LIMPPT, LREALUSRMB).

If the estimated VEC system is stable based on a series of diagnostic tests for model specifications, such as the specification tests of lag structures such as pairwise Granger causality test, a lag exclusion test, and the likelihood ratio test for lag length criteria; the residual tests such as autocorrelation Lagrange multiplier test and the Jarque-Bera normality test; and the White heteroskedasticity test, it can push the entire dynamic system toward a new equilibrium via an equilibrium adjustment process in response to any disturbances (shocks) to some variables in the system.

IV. Estimation Results

Within the so-called pan-Asian production network, the processing and assembly of imported parts and components accounts for about fifty-five percent of China's total exports and about sixty-five percent of the goods exported from China to the U.S. The processing trade in China, since it started in the late 1970s, had been rapidly growing in a sustainable manner until the world financial crisis and great recession hit in 2008 to 2009.[3] The most of foreign direct investment in China is in processing and assembly operations (Bergsten, *et al*., 2006). During the period from 2004 to 2008, China's net processing export underwent a more than six-fold increase steadily, as shown in Figure 1, while the RMB appreciated vis-à-vis the U.S. dollar by 17 percent in the nominal term and 21 percent in the real term. It is therefore expected that there exists a long-term equilibrium relationship among the real dollar/RMB exchange rate and China's processing import and export.

Table 1 summarizes the results of the unit root tests. For each of the four series, six test statistics are reported, including all the three distinctive versions (the regression without intercept, with intercept, and with intercept plus trend) of the ADF statistic and PP statistic, respectively. The three main endogenous series (LEXPPT, LIMPPT, and LREALUSRMB) demonstrate the dynamic pattern that uniformly fulfills the pre-requirement for the cointegration analysis: the

[3] According to He (2007), China's exports and imports in the form of processing trade increased from $2.5 billion in 1981 to $831.9billion in 2006, up by nearly 333 times, and its proportion in foreign trade increased from 5.7 percent to 48.6 percent.

first differences being stationary and their levels being nonstationary at the 1% significance level for all the six scenarios. For the series of LGGDP, five out of the six scenarios show the same desired pattern at 5% significance level at least and the one at 10% significance level. It follows that the appropriate estimation approach should be the co-integration analysis and vector-error correction model rather than a straight OLS regression.

The estimation of the co-integration equation for export, as reported in Table 2, is supported by the Johansen co-integration test. The λ_{trace} test statistic is statistically significant at the 5% level in rejecting the null hypothesis that there is no cointegration relationship but insignificant in rejecting the null hypothesis that there is more than one cointegration relationship. The alternative λ_{max} test yields the compatible conclusion regarding the existence and number of cointegration equations. The estimated co-integration equation suggests that processing export increases proportionately with processing import, which reflects the close dependence between processing export and processing import; in contrast, the dependence of processing export on the real exchange rate is statistically weak. Based on the likelihood-ratio test of restrictions on the cointegrating vector, LEXPPT and LIMPPT share the common cointegration trend and thus are in the cointegration space. The likelihood-ratio test of restrictions on the speed-of-adjustment coefficients indicates that LEXPPT and LIMPPT are weakly exogenous with respect to the cointegrating vectors; however, the dollar/RMB real exchange rate adjusts to the cointegrating vector in the long run to outweigh any short-term disequilibrium deviations.

Analogously, the Johansen cointegration test also suggests that there is a cointegration relationship for the import equation with processing import increasing more than proportionately in response to RMB real appreciation. Like in the estimated cointegration equation for processing export, real exchange rate does not play a significant role in the cointegration space for the processing import equation either. Nevertheless, according to the test of restrictions on adjustment coefficients, neither LIMPPT nor LREALUSRMB is weakly exogenous; that is, both of them exhibit significant endogeneity in adjusting to the cointegrating vector.

In a VEC model, the lagged differenced explanatory variables could have short-run Granger causality relations with the dependent variable if it is supported by the pairwise Granger causality test, and the long-run causality exists if the dependent variable adjusts to the long-run disequilibrium errors in a statistically significant manner (by the significance of the t-statistic for the lagged error-correction term, i.e., ECT_{t-1}). As far as the entire VEC model for export-equation system is concerned, all the lagged endogenous variables (D(LXPPT), D(LIMPPT), and D(LREALUSRMB)) exhibit their joint significance in explaining the current movement in each of the endogenous variables, which is reflected in the block exogeneity test with χ^2 (Wald) statistics. In particular, both lagged processing export and processing import Granger-cause the real dollar/RMB exchange rate in the short run via the regression of real exchange rate, and together with the real exchange rate, they demonstrate a strong joint significance at the 1% level. Finally, the short-run and long-run causality tests for the cointegration equation of import supply the compatible information. In summary of these results, Figure 2 presents a scheme of the short-run and long-run Granger causality, where it can be seen that processing export is not Granger-caused by any variables either in the short run or in the long run, suggesting that export is.

Given that the relative size of the error-correction coefficient (speed-of-adjustment coefficient) in the VEC model governs to a large extent the adjustment of the individual variables to the equilibrium, it is insightful to detect the time length of the adjustment after a departure from the equilibrium occurs. Based on the causality analysis, Table 6 reports the estimates of median lags (half-life) and mean lags, using the formulas in Doornik and Hendry (2001). The striking findings concern the sensitivity of real exchange rate to processing export and processing import in the VEC system of export cointegration in which the adjustment toward equilibrium takes around only half a year, relative to the insensitivity in the VEC system of import cointegration with a lengthy adjustment.

Table 7 provides further insight into the dynamic structure of endogenous variables via the variance decomposition of forecast error of each variable, with the emphasis on the accumulated quarterly forecast error variances only (three additional months ahead). In the VEC system of export cointegration, less than 25% of the variance in LIMPPT and less than 45% in LREALUSRMB can be explained by the source of their own variances one year after a shock impulse occurs, whereas LEXPPT is relatively exogenous in this regard since it retains nearly 75% of its own variance. Specifically, about 74% of the forecast error variance in LIMPPT is attributed to LEXPPT, which implies the exact nature of processing trade – high dependence of import upon export; and LIMPPT in turn explains about 56% of the forecast error variance in LREALUSRMB, which is also consistent with the variance-decomposition result from the VEC system of import cointegration where about 68% of the forecast error variance in LREALUSRMB is attributed to LIMPPT.

Last but not least, the remaining step is to estimate the modified Marshall-Lerner condition (2) with the estimated co-integration vector from Tables 2 and 3. Using the same symbols as in (2), the modified Marshall-Lerner condition boils down to the estimation of $1+\alpha\beta+\alpha^*-\alpha$. Referring to the co-integration equations in Table 2 and Table 3, it turns out that $\alpha=12.01$ (real exchange rate elasticity of processing import), $\beta=1.01$ (processing import elasticity of processing export), and $\alpha^*=0.02$ (real exchange rate elasticity of processing export).

It then follows that the modified Marshall-Lerner condition yields a numerical value of 1.14>0. Therefore, in the case of China, the net processing export increases rather than decreases as the real dollar/RMB exchange rate rises or the RMB appreciates vis-à-vis the U.S. dollar in real terms.

V. Concluding Remarks

This paper demonstrates the evidence that under processing trade, a real appreciation of RMB vis-à-vis the U.S. dollar helps increase rather than reduce China's net exports. The result is different both from what the orthodox theory such as Marshall-Lerner condition predicts and from what policy practitioners hope to see from the proposed RMB appreciation. The positive relationship between the dollar/RMB real exchange rate and net processing export is explained by the high import content of export due to processing trade. According to the estimated cointegration relationship from a vector error correction (VEC) model, as long as the composite export elasticity with respect to import via the real exchange rate is sufficiently large, processing exports tend to increase more than processing imports in response to a real appreciation of Chinese currency vis-à-vis the U.S. dollar. The detected dynamic structure of the VEC model suggests that Granger causality runs from processing export to processing import, which further runs to the real dollar/RMB exchange rate.

Appendix

Taking derivative of (1) with respect to ε generates (A1) below:

$$\frac{1}{\varepsilon}\left[1+\frac{\varepsilon}{M^*}\frac{\partial M^*}{\partial \varepsilon}+\frac{\varepsilon}{M^*}\frac{\partial M^*}{\partial M}\frac{dM}{d\varepsilon}-\frac{\varepsilon}{M}\frac{dM}{d\varepsilon}\right], \qquad \text{(A1)}$$

which can be rearranged into

$$\frac{1}{\varepsilon}\left[1+\frac{\varepsilon}{M}\frac{dM}{d\varepsilon}\frac{M}{M^*}\frac{\partial M^*}{\partial M}+\frac{\varepsilon}{M^*}\frac{\partial M^*}{\partial \varepsilon}-\frac{\varepsilon}{M}\frac{dM}{d\varepsilon}\right]. \qquad \text{(A2)}$$

Define α as the import elasticity with respect to the real exchange rate, β as the export elasticity with respect to import, and α* as the import elasticity with respect to the real exchange rate. Then, (2) follows.

Figure 1

Real Dollar/RMB Exchange Rate and Net Processing Export

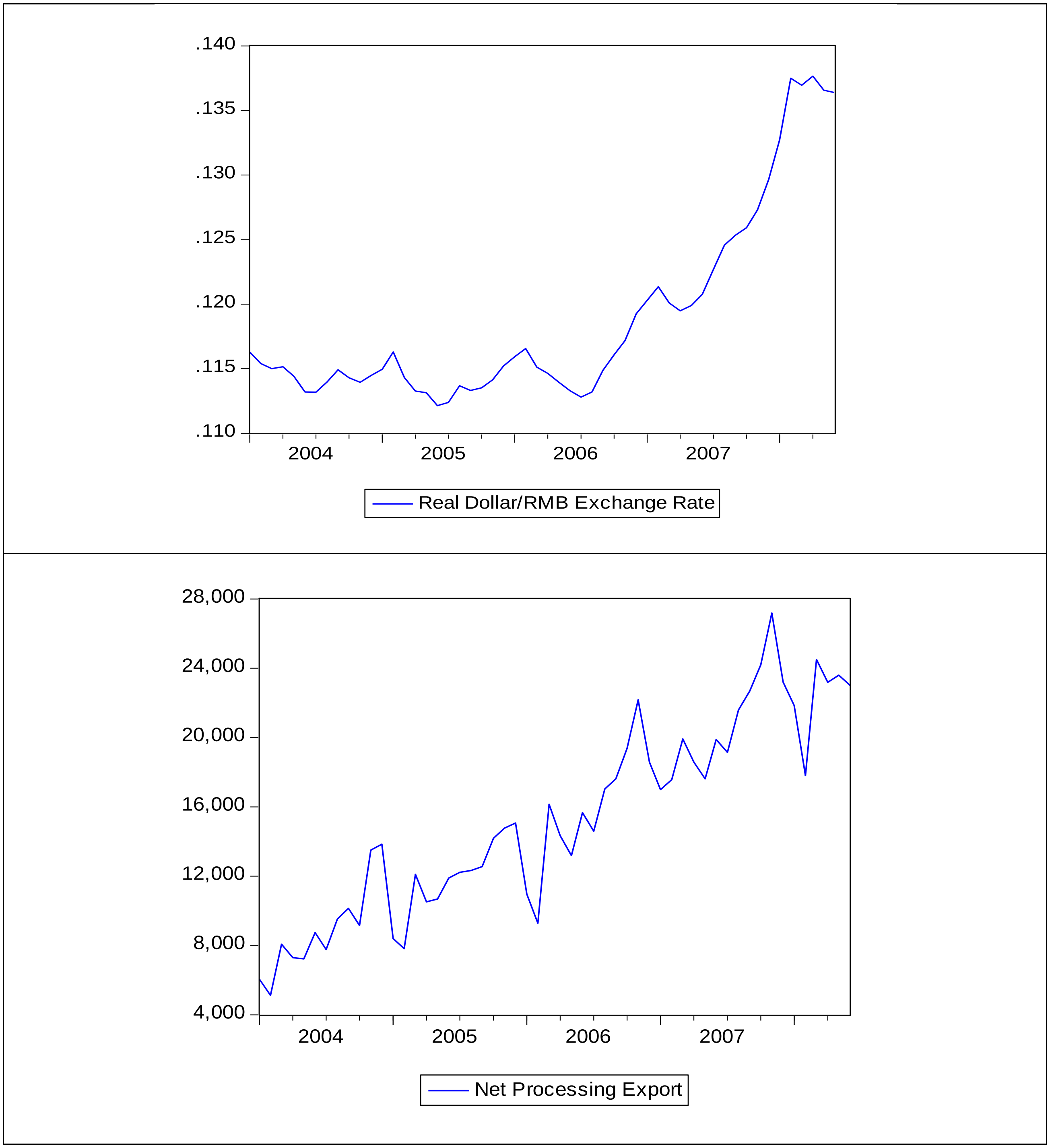


Table 1

Unit Root Tests

	ADF			PP		
	Intercept	**Intercept & Trend**	**None**	**Intercept**	**Intercept & Trend**	**None**
LEXPPT						
Level	-0.11	-1.12	1.08	-0.02	-1.12	1.17
1st Difference	-7.29***	-7.55***	-7.16***	-7.29***	-7.65***	-7.16***
LIMPPT						
Level	-0.12	-1.11	1.06	-0.06	-1.11	1.13
1st Difference	-7.17***	-7.43***	-7.06***	-7.17***	-7.52***	-7.06***
LREALUSRMB						
Level	0.39	-1.41	1.38	1.36	-0.93	2.46
1st Difference	-4.19***	-4.65***	-3.95***	-4.19***	-4.32***	-3.95***
LGGDP						
Level	-2.21	-2.64	-0.04	-1.62	-1.62	0.09
1st Difference	-3.32**	-3.36*	-3.35***	-3.37**	-3.29*	-3.40***

Note: The figures with *** are significant at 1% level, those with ** are significant at 5% level, those with * are significant at 10% level.

Table 2

Johansen Co-integration Analysis of Export Equation

Johansen Co-integration Test

Cointegration Equation: LEXPPT = 0.27 + 1.01LIMPPT +0.02LREALUSRMB
(180.94)*** (0.10)

	Eigenvalue	H_0	H_1	Statistic	5% c.v.	Prob.
λ_{trace} test						
	0.51	r=0	r>0	47.52	28.79**	0.00
	0.20	r≤1	r>1	12.26	15.49	0.14
λ_{max} test						
	0.51	r=0	r=1	35.26	21.13**	0.00
	0.20	r=1	r=2	10.98	14.26	0.15

Significance Test of Variables in the Cointegrating Vector

Restrictions	β_{LEXPPT}=0	β_{LIMPPT}=0	$\beta_{LREALUSRMB}$=0
$\chi^2(1)$	21.79***	22.22***	0.006

Significance Test of Speed-of-Adjustment Coefficient to the Cointegrating Vector

Restrictions	α_{LEXPPT}=0	α_{LIMPPT}=0	$\alpha_{LREALUSRMB}$=0
$\chi^2(1)$	1.78	2.21	21.45***

Note: In the co-integration equation, the figures in the parentheses are t-values, and the symbol r in the table of cointegration test denotes the number of cointegrating equations. In all the tables, the estimates with *** are significant at 1% level, those with ** are significant at 5% level, and those with * are significant at 10% level.

Table 3

Johansen Co-integration Analysis of Import Equation

Johansen Co-integration Test

Cointegration Equation: LIMPPT = -2.15 +12.01LREALUSRMB+0.14TREND
(1.87)* (5.23)***

	Eigenvalue	H_0	H_1	Statistic	5% c.v.	Prob.
λ_{trace} test						
	0.46	r=0	r>0	38.62	25.87**	0.00
	0.15	r≤1	r>1	7.97	12.51	0.25
λ_{max} test						
	0.46	r=0	r=1	30.65	19.38**	0.00
	0.15	r=1	r=2	7.97	12.51	0.25

Significance Test of Variables in the Cointegrating Vector

Restrictions	$\beta_{LIMPPT}=0$	$\beta_{LREALUSRMB}=0$
$\chi^2(1)$	17.74***	2.34

Significance Test of Speed-of-Adjustment Coefficient to the Cointegrating Vector

Restrictions	$\alpha_{LIMPPT}=0$	$\alpha_{LREALUSRMB}=0$
$\chi^2(1)$	7.36***	17.59***

Note: In the co-integration equation, the figures in the parentheses are t-values, and the symbol r in the table of cointegration test denotes the number of cointegrating equations. In all the tables, the estimates with *** are significant at 1% level, those with ** are significant at 5% level, and those with * are significant at 10% level.

Table 4

Short-Run and Long-Run Granger Causality from the VEC Model of Export Equation

		χ^2 Statistics (for excluded variables)			t Statistic for ECT_{t-1}
	D(LEXPPT)	D(LIMPPT)	D(LREALUSRMB)	Block Exogeneity	
D(LEXPPT)	–	2.16	0.71	4.62*	1.45
D(LIMPPT)	2.31	–	0.57	4.50*	1.62*
D(LREALUSRMB)	7.82***	8.69***	–	23.87***	5.00***

Table 5

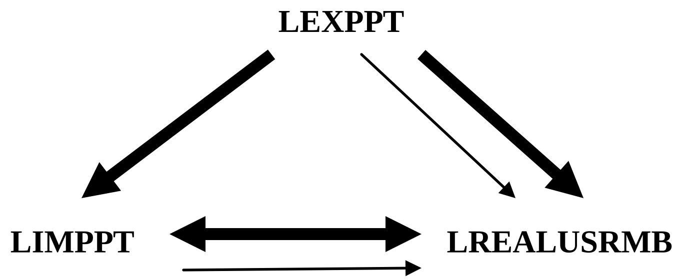
Short-Run and Long-Run Granger Causality from the VEC Model of Import Equation

	χ^2 Statistics (for excluded variables)		t Statistic for ECT_{t-1}
	D(LIMPPT)	D(LREALUSRMB)	
D(LIMPPT)	–	0.44	-2.91***
D(LREALUSRMB)	37.07***	–	-4.93***

Note: ECT_{t-1} represents the error correction term in the regressions equations of the VEC model. In all the tables, the estimates with *** are significant at 1% level, those with ** are significant at 5% level, and those with * are significant at 10% level.

Figure 2

Scheme of the Short-Run and Long-Run Granger Causality



Note: The thick arrows represent a long-run Granger causality relationship and thin arrows a short-run Granger causality relationship. The double-arrow line indicates bi-directional Granger causality and the single-arrow line unidirectional Granger causality. The causality outcomes are based on the results reported in Tables 2 through 5.

Table 6

Speed of Adjustment Estimates

	Export Equation with LREALUSRMB as Dependent		**Import Equation**	
			LIMPPT as Dependent	**LREALUSRMB as Dependent**
	$\alpha_{LREALUSRMB}$=0.14		α_{LIMPPT}=-0.48	$\alpha_{LREALUSRMB}$= -0.005
	$\gamma_{D(LEXPPT)}$ =-0.07	$\gamma_{D(LIMPPT)}$ =0.08	$\gamma_{D(LREALUSRMB)}$ =-7.05	$\gamma_{D(LIMPPT)}$ =0.007
Mean Lag	7.64	6.57	16.77	198.6
Median Lag (Half Life)	5.07	4.06	4.24	137.2

Note 1: The subscript in the symbol α represents the name of the dependent variable that responds to the error correction term in the VEC equation for the same dependent variable, whereas the subscript in the symbol γ represents the name of the independent variable to which the same dependent variable responds.

Note 2: The formulas for computing mean lag and median lag are from Doornik and Hendry (2001).

Table 7

Variance Decomposition

VEC Model with the Co-Integration Equation of Export

	% of forecast error variance explained by innovation in:			
Variance Decomposition of	Month	**LEXPPT**	**LIMPPT**	**LREALUSRMB**
LEXPPT	3	96.05	3.23	0.70
	6	83.97	13.67	2.34
	9	77.38	19.31	3.30
	12	73.64	22.51	3.84
LIMPPT	3	96.23	3.16	0.60
	6	84.27	13.46	2.26
	9	77.63	19.12	3.23
	12	73.85	22.35	3.79
LREALUSRMB	3	9.58	25.10	65.31
	6	3.16	48.60	48.23
	9	1.86	54.17	43.96
	12	1.35	56.49	42.14

VEC Model with the Co-Integration Equation of Import

	% of forecast error variance explained by innovation in:		
Variance Decomposition of	Month	**LIMPPT**	**LREALUSRMB**
LIMPPT	3	99.98	0.01
	6	99.50	0.49
	9	97.85	2.14
	12	96.32	3.67
LREALUSRMB	3	9.06	90.93
	6	51.77	48.22
	9	64.69	35.30
	12	68.76	31.23

Note: The Cholesky ordering in the equation equation is based on the order in the normalized cointegration vector: LEXPPT, LIMPPT, LREALUSRMB, and the Cholesky ordering in the import equation is similarly determined as: LIMPPT, LREALUSRMB.

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