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Abstract

This note, allowing for an effective won exchange rate, aims to refine Korea's monetary interaction model obtained by Choo and Kurita (2011, *International Review of Economics and Finance*, 20, 267-280). A multivariate cointegration analysis of Korean quarterly time series data reveals three theory-consistent cointegrating relationships: (i) a money demand relationship subject to the currency substitution effect, (ii) a monetary policy rule relationship, and (iii) an exchange rate determination relationship. The results of the analysis demonstrate various roles played by the effective won rate in the overall economy, shedding useful light on Korea's future macroeconomic policy.

JEL classification: C32; E41; E52; F31
Keywords: Korean economy; Effective exchange rate; Monetary interaction; Money demand; Monetary policy rule; Cointegrated vector autoregressive model.

I. Introduction

Choo and Kurita (2011), denoted hereafter as CK, conduct an empirical study of monetary interaction in Korea. Paying close attention to important roles played by broad money and the interest rate term spread, the empirical analysis in CK has successfully revealed two theory-consistent cointegrating relationships: a standard broad money demand function and a Taylor-type monetary policy rule function (see Taylor, 1993). It is further demonstrated that the past values of aggregate money play a significant part in a cointegrated system for Korea, thereby contributing to macroeconomic forecasting. The

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empirical success achieved by CK is surely remarkable, but there is a caveat in the interpretation of their results. That is, the analysis of CK has not explicitly taken exchange rates into account in their monetary model for the Korean economy, so it is difficult to figure out the roles of exchange rates in monetary interaction in the economy. Let us note that Korea has been operating under a flexible exchange rate regime since 1980.

Although CK has successfully attained a data-congruent econometric model of the Korean economy, there is still a possibility that the model may be further refined by explicitly incorporating a Korean won effective exchange rate into it. One may conceive of at least two theoretical reasons for the justification of this possibility. Let us consider these in turn.

Firstly, money demand *can* be affected by an effective exchange rate. If the appreciation of domestic currency induces expectation of further appreciation, individuals as well as institutional investors are likely to substitute domestic money for foreign assets. At the same time, such appreciation leads to a fall in the domestic currency value of various foreign financial assets held by domestic agents; if this is perceived as a virtual decrease in the value of their wealth, the demand for domestic currency could also be on the decline. The former is called the currency substitution effect, while the latter is referred to as the wealth effect. See Miles (1978), Batten and Hafer (1984), Arize (1991), Karfakis (1991), Darrat *et al.* (1996), Bahmani-Oskooee and Shin (2002), Hsieh and Hsing (2009), *inter alia*, for further details. In the presence of either of the effects, the independence of monetary policy under a flexible exchange rate regime would be undermined; see Friedman (1953) and Miles (1978), *inter alia*.

Secondly, the monetary authority may take into account an effective exchange rate, in addition to national income and inflation, when implementing a rule-based monetary policy. The authority may lower the official interest rate in the face of currency appreciation, for the appreciation could cause an economic slowdown through the deterioration of international price competitiveness. See Eichengreen (2004), *inter alia*.

Motivated by these conceivable roles played by an effective exchange rate in a macro economy, this note aims to refine CK's monetary interaction model by allowing for an effective won exchange rate. The empirical analysis in this note employs quarterly time series data for a period running from the late 1980s to the beginning of 2010. This note is seen as a complement to CK, and will be a useful reference, coupled with CK, for the development of Korea's future macroeconomic policy.

The organization of the rest of this note is as follows. Section II presents a canonical model and briefly reviews a likelihood-based analysis of a cointegrated vector autoregressive (CVAR) system. Section III performs an econometric analysis of the data in the Korean economy. A summary and conclusion are given in Section IV. All the analyses and graphics in this note use *OxMetrics/PcGive* (Doornik and Hendry, 2007).

II. Canonical model and a review of CVAR analysis

This section, based on CK, presents a modified canonical theoretical model subjected to a multivariate cointegration analysis; the model is modified to the extent that it now contains the variable of a nominal effective exchange rate. This section also briefly reviews the framework of a likelihood-based CVAR analysis of non-stationary time series data integrated of order 1, denoted hereafter as $I(1)$. See CK for details.

Let us introduce a vector X_t defined as follows:

$$X_t = \left(m_t - p_t, y_t, i_t^s - i_t^l, \pi_t, s_t\right)',$$

where m_t, p_t, y_t, and s_t denote the logarithms of nominal money balance, price level, national income, and a nominal effective exchange rate, respectively, while i_t^s, i_t^l, and π_t are short-term interest rate, long-term interest rate, and inflation rate, respectively. In regard to the broad money demand function, the following specification is presumed:

$$m_t - p_t = \gamma_0 + y_t - \gamma_1\left(i_t^l - i_t^s + \pi_t\right) + \gamma_2 s_t, \qquad (1)$$

where $\gamma_1 > 0$ and $\gamma_2 \neq 0$. Following CK, the price homogeneity, the unit income elasticity, the same absolute value of coefficients for i_t^s, i_t^l, and π_t are assumed in (1), combined with a newly-introduced feature, that is, the existence of currency substitution or wealth effects associated with s_t. If $\gamma_2 > 0$, this then implies the effect of currency substitution, while $\gamma_2 < 0$ indicates the wealth effect instead. See Karfakis (1991), *inter alia*, for empirical evidence in favor of such a specification as equation (1). Note that a rise in s_t denotes an appreciation of domestic currency in terms of foreign currencies. Whether such parametric properties as shown in equation (1) are empirically valid or not is the first question of interest in the analysis below.

Let us turn to a monetary policy rule function, which is presumed as follows:

$$i_t^s - i_t^l = \mu_0 + \mu_1(y_t - \theta_1 t) + \mu_2\,\pi_t - \mu_3 s_t, \qquad (2)$$

where $\mu_i > 0$ for $i = 1, 2, 3$. Based on the results in CK, it is assumed in equation (2) that the potential output and target inflation rate show a (log) linear deterministic trend, that the real long-term interest rate is time-invariant, and that there is a one-to-one effect from i_t^l to i_t^s. Note that, distinct from CK, s_t is explicitly incorporated into equation (2), reflecting the possibility that monetary policy may be influenced by the effective exchange rate behavior. Whether such a long-run relation as equation (2) is revealed from the data, including the question of either $\mu_3 = 0$ or not, is counted as the second empirical query of interest in the analysis below.

The empirical exploration in CK has revealed two cointegraing relationships, basically in accordance with equations (1) and (2) above, apart from the nominal exchange rate. Since the inclusion of s_t in the model leads to an increase in the dimension of a vector autoregression, we may encounter an additional economically meaningful long-run relation in the empirical analysis below. Recalling that CK reveals a useful feature of Korea's monetary economy, where national income is weakly exogenous for the parameters of interest (see Engle *et al.*, 1983), one might expect a new financial feature explaining the exchange rate behavior in an expanded five-variable model. Following the real interest differential model of Frankel (1979), we propose an exchange rate function as follows:

$$s_t = \delta_0 - \delta_1[(m_t - p_t) - (m_t^* - p_t^*)] + \delta_2(y_t - y_t^*) \\ +\delta_3(i_t^s - i_t^{s*}) - \delta_4(\pi_t - \pi_t^*), \tag{3}$$

where * denotes variables for the rest of the world and $\delta_i > 0$ for $i = 1, \cdots, 4$. The long-term interest differential may be viewed as representing the relative inflation, which allows us to rearrange equation (3) as follows:

$$s_t = \delta_0 - \delta_1[(m_t - p_t) - (m_t^* - p_t^*)] + \delta_2(y_t - y_t^*) \\ +\delta_3(i_t^s - i_t^{s*}) - \delta_4(i_t^l - i_t^{l*}), \tag{4}$$

Further, with the variables for the rest of the world being assumed to be fixed, equation (4) becomes

$$s_t = \delta_0' - \delta_1(m_t - p_t) + \delta_2 y_t + \delta_3 i_t^s - \delta_4 i_t^l, \tag{5}$$

where δ_0' denotes a combined intercept consisting of δ_0 and the variables for the rest of the world. The assumption that the rest of the world variables are treated as fixed could be justified as a result of aggregating various macroeconomic variables possibly offsetting each other's behavior. Based on a previous empirical study on Korea by Kim and Kwon (2003), where δ_1 and δ_2 are estimated approximately the same, while δ_3 and δ_4 are almost the same in (5), an additional long-run relation may be proposed for exchange rate determination as follows:

$$s_t = \delta_0' + \delta_1(y_t - m_t + p_t) - \delta_3(i_t^l - i_t^s). \tag{6}$$

That is, when the velocity of money $(y_t - m_t + p_t)$ rises, or the term spread $(i_t^l - i_t^s)$ falls, domestic currency appreciates. Let us also note that one may, instead of (6), conceive an equation for inflation determination, which also seems to be a reasonable candidate for a long-run economic relationship; but it turns out that such an inflation-oriented relationship is not revealed in the following empirical analysis. See Yazgan and Zer-Toker (2010) for the analysis of inflation determination.

Equations (1), (2) and (6) above are seen as candidates for empirical cointegrating relationships pursued in the CVAR analysis in this note. Let us then briefly review the framework for a likelihood-based CVAR analysis of $I(1)$ data. See CK for details. Following Johansen (1996), the CVAR(k) model for a 5-dimensional time series, $X_{-k+1},\cdots,X_T$, is given by

$$\Delta X_t = \alpha(\beta', \gamma)\begin{pmatrix} X_{t-1} \\ t \end{pmatrix} + \sum_{i=1}^{k-1} \Gamma_i \, \Delta X_{t-i} + \mu + \Phi D_t + \varepsilon_t, \text{ for } t = 1,\cdots,T, \qquad (7)$$

where D_t is a q-dimensional vector of deterministic terms apart from constant and trend, such as seasonal and impulse dummies, and the innovations $\varepsilon_1,\cdots,\varepsilon_T$ have independent and identical normal $N(0,\Omega)$ distributions conditional on the initial values $X_{-k+1},\cdots,X_0$. The parameters are defined as $\alpha,\beta \in \mathbf{R}^{5\times r}$, $\gamma \in \mathbf{R}^r$ for $r < 5$, $\mu \in \mathbf{R}^5$, $\Gamma_i,\Omega \in \mathbf{R}^{5\times 5}$, and all of them vary freely; Ω is a positive definite matrix. Let us define $\beta^{*\prime} = (\beta', \gamma)$ and $X_{t-1}^* = (X_{t-1}', t)'$ for future reference. A set of vectors α is called adjustment vectors, while β^* is referred to as cointegrating vectors; the index r denotes cointegrating rank. The linear combinations, $\beta^{*\prime}X_{t-1}^*$, represent cointegrating relationships, some or all of them possibly corresponding to the empirical expressions of equations (1), (2) and (6) above. See Johansen (1996) for details of the CVAR analysis. Equation (7) provides a basis for the empirical analysis performed in this note.

III. An extended CVAR analysis of Korean time series data

We are now in a position to conduct a CVAR analysis of Korean time series data, the basis of which is provided by CK. As compared with CK, the dataset of this note is extended in the following respects: (i) it contains the data of the log of nominal effective Korean won rate and (ii) the sample period available for estimation runs from the first quarter in 1987 to the first quarter in 2010 (denoted as 1987.1 – 2010.1, hereafter). An empirical analysis of the extended dataset may indicate the presence of such long-run economic linkages as demonstrated in the canonical model above. The sources of the data are the *International Financial Statistics* (*IFS*), the International Monetary Fund, and the *Economic Statistics System*, the Bank of Korea. The variables of interest are defined as follows:

$m_t - p_t =$ the log of the average of monthly liquidity aggregate of financial institutions (a modification of the previous M3) $-$ the log of a consumer price index

(CPI),

y_t = the log of the real gross domestic product (GDP),

$i_t^s - i_t^l$ = the overnight call rate − the yield on the national housing bond,

π_t = the percentage change in CPI over the previous four quarters *i.e.* $\Delta^4 p_t$,

s_t = the log of an *IFS*-supplied nominal effective Korean won rate.

In addition, let us note that the CPI is adopted here as a measure of price level and inflation, instead of the GDP deflator index employed in CK. This is because we attempt to find hard evidence in support of the validity of Korea's monetary interaction model regardless of the choice of price indices. These five variables are bundled in a vector X_t as shown above, which allows us to formulate an unrestricted five-dimensional VAR model. The lag length of the VAR model is set at 4 based on *F*-test statistics for the lag order selection. The same dummy variables as those employed by CK are included in the model, together with an additional dummy variable defined as $D_{4,t} = 1(2008.4)$ and 0 otherwise. This additional dummy variable corresponds to a global economic depression triggered by the US financial crisis in 2008.4. According to a battery of diagnostic tests of the model's residuals, there is no strong evidence against the assumption of normality and temporal independence; this is in accordance with CK. We are therefore able to proceed to the likelihood-based cointegrated VAR analysis.

	$r = 0$	$r \leq 1$	$r \leq 2$	$r \leq 3$	$r \leq 4$
$\log LR$	160.13[0.00]*	104.79[0.00]*	55.66[0.00]*	26.33[0.04]	6.93[0.36]

Note: * denotes significance at the 1% level.

Table 1. The determination of the cointegrating rank

Table 1 presents a set of log likelihood ratio test statistics for the cointegrating rank, denoted as $\log LR$. The test statistics are seen as strong statistical evidence for the rejection of the null hypotheses of $r = 0$, $r \leq 1$ and $r \leq 2$, while the hypothesis of $r = 3$ cannot be rejected at the 1% significance level. Recalling that the cointegration analysis in CK supports $r = 2$, we judge that it is reasonable to obtain statistical evidence in favor of $r = 3$ in the present extended VAR system encompassing CK's small system. Thus we choose $r = 3$, which paves a way for further CVAR analysis.

The determination of the cointegrating rank allows us to estimate (7), by which we need to inspect various joint restrictions on the adjustment and cointegrating vectors. Cointegrating relationships, as shown by Johansen (1996, Ch.3), represent attractor sets existing in the VAR system. It is thus important to identify a set of meaningful cointegrating combinations and also to check how adjustment mechanisms work in the system. Guided by the canonical model above and the empirical results in CK, we arrive at the following acceptable restrictions:

$$\hat{\alpha}\,\hat{\beta}^{*\prime}X_{t-1}^{*}=\begin{pmatrix}\underset{(0.01)}{-0.04} & \underset{(-)}{0} & \underset{(-)}{0}\\ \underset{(-)}{0} & \underset{(-)}{0} & \underset{(-)}{0}\\ \underset{(0.04)}{-0.23} & \underset{(0.09)}{-0.50} & \underset{(0.005)}{0.02}\\ \underset{(0.04)}{-0.16} & \underset{(0.08)}{0.22} & \underset{(0.004)}{0.02}\\ \underset{(0.17)}{0.44} & \underset{(-)}{0} & \underset{(0.02)}{-0.06}\end{pmatrix}$$

$$\times\begin{pmatrix}\underset{(-)}{1} & \underset{(-)}{-1} & \underset{(-)}{-1} & \underset{(-)}{1} & \underset{(0.03)}{-0.08} & \underset{(-)}{0}\\ \underset{(-)}{0} & \underset{(0.02)}{-0.19} & \underset{(-)}{1} & \underset{(0.09)}{-0.69} & \underset{(-)}{0} & \underset{(0.0002)}{0.0012}\\ \underset{(-)}{8.50} & \underset{(0.24)}{-8.50} & \underset{(2.15)}{-14.69} & \underset{(-)}{0} & \underset{(-)}{1} & \underset{(-)}{0}\end{pmatrix}\begin{pmatrix}m_{t-1}-p_{t-1}\\ y_{t-1}\\ i_{t-1}^{s}-i_{t-1}^{l}\\ \pi_{t-1}\\ s_{t-1}\\ t\end{pmatrix}, \quad (8)$$

where the figures in the parentheses are standard errors. The log *LR* test statistic for the joint restrictions amounts to only 4.52, with its *p*-value according to $\chi^2(9)$ given by 0.87. Thus, the joint null hypothesis is not rejected even at the 10% level; the restricted cointegrating combinations indicated in (8) can be seen as equilibrium correction terms in the VAR system. These combinations are denoted as $ecm_{1,t}$, $ecm_{2,t}$ and $ecm_{3,t}$, respectively; according to (8), the specific forms of them are expressed as follows:

$$\begin{aligned}ecm_{1,t} &= m_t - p_t - y_t + (i_t^l - i_t^s + \pi_t) - 0.08 s_t,\\ ecm_{2,t} &= i_t^s - i_t^l - 0.19\,(y_t - 0.006t) - 0.69\pi_t,\\ ecm_{3,t} &= s_t - 8.5(y_t + p_t - m_t) + 14.69\big(i_t^l - i_t^s\big).\end{aligned}$$

Note that these long-run relations are not mean-zero in general, and so it is possible to compute a non-zero constant term corresponding to the mean of each relation.

Let us consider the economic interpretation of each relationship above. The first cointegrating relationship $ecm_{1,t}$ corresponds to equation (1) above, thus $ecm_{1,t}$ can be seen as an empirical representation of aggregate money demand in Korea. The relationship $ecm_{1,t}$ is fairly similar to the first cointegrating relationship ($c_{1,t}$) found by CK. The critical differences between $ecm_{1,t}$ and $c_{1,t}$ are: (i) $ecm_{1,t}$ contains s_t as a significant component of the long-run relationship, and (ii) as a result of the inclusion of s_t, the value of the coefficient for $(i_t^s - i_t^l - \pi_t)$ in $ecm_{1,t}$ has become smaller than that of $c_{1,t}$. Solving $ecm_{1,t}$ for the real money allows us to find that the effective won rate has a positive influence on the aggregate real money. It is thus possible to reason that the won rate may have a significant currency substitution effect, instead of a wealth effect, on the long-run behavior of Korea's aggregate money demand. Let us also mention, however, that it could be difficult to assert the observed currency substitution effect in $ecm_{1,t}$ is very strong, judging from the relatively large standard error of the coefficient for s_t reported in (8).

The second cointegrating relationship $ecm_{2,t}$, corresponding to equation (2) for $\mu_3 = 0$ above, is perceived as Korea's monetary policy rule function; $ecm_{2,t}$ is almost identical to the second cointegrating relationship ($c_{2,t}$) revealed by CK. It should be noted that the effective Korean won rate does not play any significant role in the second cointegrating relationship. This finding indicates the possibility that Korea's monetary authority may tend to attach less importance to the exchange rate behavior than to other variables such as inflation. However, in the presence of the possible currency substitution effect in the money demand, the monetary authority may not be able to implement monetary policy completely independent of the behavior of the effective won rate. That is, the floating exchange rate regime is unable to insulate the economy from various monetary influences of the rest of the world (See Friedman, 1953; Miles, 1978).

Finally, the third relationship, $ecm_{3,t}$, may be seen as a long-run linkage among the effective won rate, the velocity of money, and the term spread. Solving this equation for the effective won rate and treating the term $ecm_{3,t}$ as a stationary error, one finds that the won rate tends to move in the same direction as the velocity of money while opposite to the term spread. This long-run relation is in line with equation (6), presented in the previous section. Thus, one may perceive $ecm_{3,t}$ as a long-run relationship consistent with the real interest differential model suggested by Frankel (1979).

Next, let us check the adjustment structure of each equation in the CVAR system, indicated by the results in equation (8). According to $\hat{\alpha}$ in (8), $m_t - p_t$ exclusively adjusts to $ecm_{1,t-1}$, while s_t reacts to both $ecm_{1,t-1}$ and $ecm_{3,t-1}$. The adjustment mechanisms seem to be consistent with the economic interpretations of $ecm_{1,t-1}$ and $ecm_{3,t-1}$ suggested above. In contrast, both $i_t^s - i_t^l$ and π_t are influenced by all of the disequilibrium errors generated by $ecm_{1,t-1}$, $ecm_{2,t-1}$ and $ecm_{3,t-1}$; that is, we observe various spillover effects of equilibrium correction in the behavior of the term spread and inflation rate. Finally, y_t does not react to any disequilibrium errors, and thus this variable is judged to be weakly exogenous for the cointegrating parameters.

Let us recall that the cointegrated VAR model above, as compared with that in CK, is modified such that the effective won rate is newly introduced, the CPI is employed instead of the GDP deflator, and the sample period for estimation is extended. It is noteworthy that, despite these changes, two of the cointegrating linkages derived above, that is, $ecm_{1,t}$ and $ecm_{2,t}$, are basically consistent with those revealed in CK. This finding is seen as evidence supporting the robustness of the Korean model in CK. In addition, one should note that the newly-derived linkage, $ecm_{3,t}$, is interpretable as a long-run economic relationship centering on the effective won rate.

Lastly, the data are mapped to the $I(0)$ space by differencing and using the set of restricted cointegrating relations, so that we can estimate a partial vector equilibrium correction model conditional on Δy_t, the weakly exogenous variable in the overall system. Figure 1 presents the fitted values of all the endogenous variables in the partial model, coupled with the corresponding actual values. The tracking appears to be fairly close, thus supporting the view that the model including the effective won rate is successful in representing Korea's macroeconomic series over the period of 1987-2010.

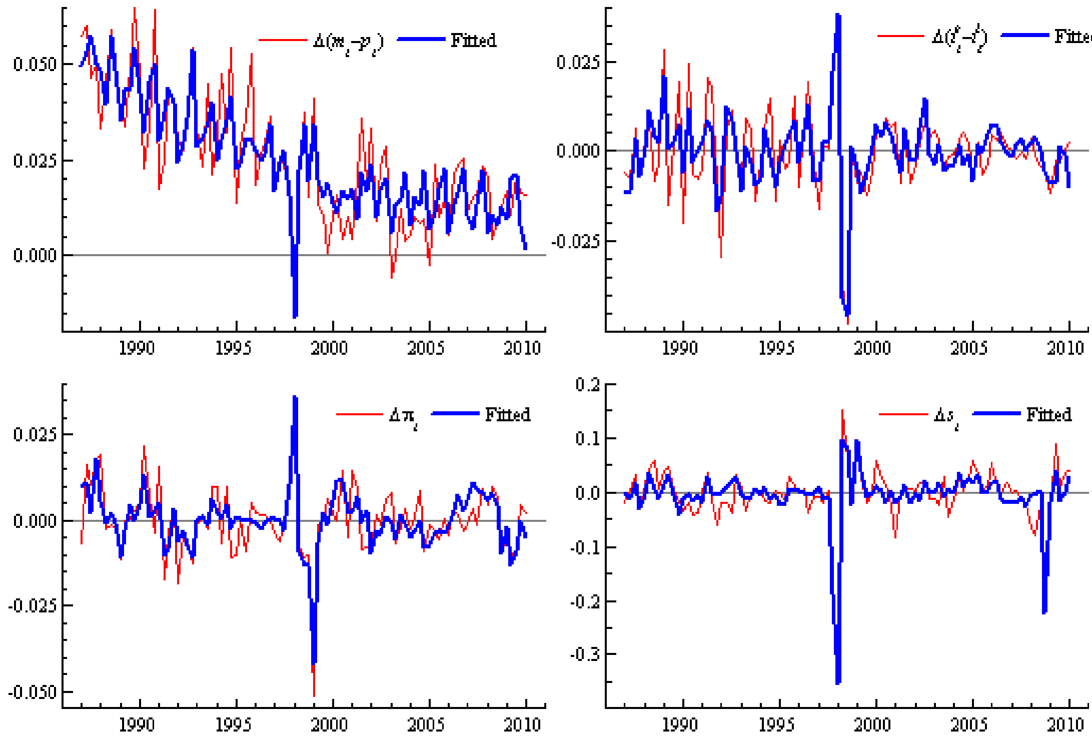

Figure 1. Fitted values of the partial vector equilibrium correction model

Ⅳ. Summary and conclusion

Encouraged by the possibility that an effective exchange rate can play various significant roles in a macro economy, this note aims at refining CK's monetary interaction model for Korea by taking account of an effective won exchange rate. The empirical study uses quarterly time series data for the period 1987.1 – 2010.1. A multivariate cointegration analysis of Korean data reveals three theory-consistent long-run relationships: the first corresponds to a money demand function with a plausible currency substitution effect, the second is seen as a Taylor-type monetary policy rule function free from direct long-run influences of the effective won rate, and the third is perceived as a real interest differential model for the effective won rate. The evidence for the currency substitution effect appears to be noteworthy. It should be pointed out, at the same time, that the effect itself does not seem to be very strong in equation (8) and, in addition, the previous study by CK reveals a stable money demand function with exchange rates excluded. The effect of currency substitution may become stronger in the near future, as the Korean economy becomes more closely integrated with the world capital market.

Let us also recall the accepted view that, given the presence of a currency substitution effect, the monetary authority is in general unable to enjoy the independence of monetary policy implementation under a flexible exchange rate regime. In other words, because of the effect, even the floating exchange rate regime cannot insulate the economy in question from monetary development in the rest of the world (See Friedman, 1953; Miles, 1978). The possible effect of currency substitution, as shown in equation (8), may thus shed some light on the issue of Korea's monetary policy independence. Let us, also, mention one piece of evidence in Korea consistent with the received view above: Korea's domestic inflation, in fact, has not been insulated completely from foreign shocks (see Kim and Lee, 2004).

Moreover, it is known that, with currency substitution affecting the behavior of money demand, exchange rates may tend to be unstable (See Girton and Roper, 1981); this possibility could in part explain the volatile development in the actual exchange rate in Korea since its adoption of floating exchange rate regime. Further, it is understandable that the Korean monetary authority has accumulated a large stock of foreign exchange reserves, in effect as a buffer stock to avoid exchange rate volatility produced by currency substitution.

Overall, the empirical analysis in this note reveals various roles played by the effective won rate in the Korean economy. This note is recognized as a complement to CK in the sense that valuable information on the economy is shown and discussed. Both CK and this note promise to be useful references for the development of Korea's macroeconomic policy in the future.

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