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CAN KOREA PROTECT ITSELF FROM INTERNATIONAL CAPITAL FLOWS: ESTIMATES OF MONETARY STERILIZATION*

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The study investigates the external influences on Korea's monetary policy over the period from 1990 to 2020. The focus is on the effects of US interest rates, payments imbalances and exchange rate changes on Korean monetary policy. The estimation of the Taylor rule measures the effects on Korean interest rates and the estimation of sterilization/offset coefficients measures the effects on the domestic money supply and monetary base. This study measures the sterilization/offset equations and compares the results with the ones from Koo (2004) which examines the Taylor rule study. The empirical tests of both studies reveal two key findings: (1) Korean monetary policy has been influenced by monetary developments in the US, but it still has had a good deal of independence. (2) The exchange rate plays a crucial role for the BOK in achieving independent monetary policy.

Keywords: Korean Monetary Policy, US Interest Rates, Sterilization and Offset Coefficients, Exchange Rate, Korean Interest Rate
JEL Classification: D78, E52, F30, G01

1. INTRODUCTION

Some have argued that in a world of globalization countries have little ability to follow independent monetary policies in the absence of strict capital controls. Korea offers an excellent opportunity since it is an open economy without stringent capital controls. The main purpose of this study is to investigate the external influences on Korea's monetary policy over the period from 1990 to 2020.[1] Specifically, the focus will be on the effects of US interest rates and exchange rate changes. policy. Two types of measures of monetary policy will be compared. These are the effects on Korean

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1 The time period is chosen because of data availability.

interest rates and the effects on the domestic money supply and monetary base, the two standard ways in which monetary policy is measured.[2]

The purpose in estimating the basic Taylor rules is to go beyond unconditional estimates of pass through from US to Korean interest rates and to attempt to control for domestic influences on Korean interest rates. This gives us better estimates of the actual influences of the US interest rate and exchange rate changes by controlling for Korean interest rate changes that would have occurred even without the foreign developments.[3] Correspondingly, the estimation of the sterilization and offset coefficients by a set of simultaneous equations attempts to control for domestic as well as external influences on its money supply.

This study focuses on the estimation of the simultaneous equations that measure the sterilization and offset coefficients. The results of this study will be compared to the results from the study, Koo (2024), which presents the results on interest rates based on a Taylor rules type study.

Estimating both the Taylor rule and sterilization/offset coefficients together can give a better idea of the patterns of Korean responses. Specifically, estimating both equations will help us see if they give clues about whether Korea is able to use sterilization to limit the effects of US policies on its exchange rate and interest rate. Also, a careful comparison of the extent to which the estimates yield the same or different results will be made. Our study is unique because it considers both the Taylor rule and sterilization policy when the spillover effects from the US to emerging economies are examined. Previous studies have looked at only one or the other regarding the spillover effects. We find that external influences do have an effect on Korean monetary policy but that the central bank still has a considerable scope for independent action.

The paper is organized as follows. Section 2 contains the literature review of the sterilization and offset coefficients. Section 3 explains methodologies, data and other issues. Section 4 shows the empirical results and Section 5 concludes.

2. LITERATURE REVIEW OF THE STERILIZATION AND OFFSET COEFFICIENTS: BRIEF BACKGROUND OF THE PAST EMPIRICAL METHODOLOGIES OF ESTIMATING THE EXTENT OF STERILIZATION

The sterilized intervention has been used widely in exchange rate regimes of managed flexibility and also in pegged regimes. It allows exchange market developments to be separated from domestic monetary policy in the short run (Willett,

[2] For the balance of payments, I refer to the overall or official settlements balance which corresponds to changes in international reserves. That's the influence that I am testing with the sterilization coefficients in terms of effects on the money supply.

[3] I compare these results with those of simple pass-through estimates to see how much difference there is.

2009). Even under fixed exchange rate regimes with imperfect capital mobility, sterilization is one of the monetary policies that can be performed.

However, it will be helpful to investigate the effectiveness of such intervention for Korea in depth by analyzing the degree of capital mobility, the scope of sterilization and de fact exchange rate regimes of for Korea. The attempts to measure the quantitative effects of the variables may be needed because slight differences in the classification of the variables can lead to different results. For instance, highly mobile capital movements are sometimes regarded as having perfect capital mobility. Also, de facto managed floating exchange rate regime is regarded as de jure floating exchange regime. Thus, measuring the sterilization coefficient, offset coefficient and using de facto exchange rate regime as indicators will offer more realistic conclusions.

To estimate the scope of sterilization, I cannot just examine the correlations between the reserve changes and the base (or money supply) because I would not know what variables are exogenous and endogenous. Thus, it may be helpful to examine the types of equations used to derive sterilization and offset coefficients in other papers.

Ouyang et al. (2010) classified the following three groups of current studies that estimate the extent of sterilization from the earlier simple model to more advanced simultaneous equations.

The first group of the studies estimated sterilization coefficients on the monetary policy reaction function of central banks such as the following:

$$\Delta NDA_t = c_0 + c_1 \Delta NFA_t + X\beta + u_t, \tag{1}$$

where ΔNDA_t and ΔNFA_t represent the change in net domestic assets and net foreign assets, respectively. X represents other explanatory variables that might influence a monetary authority's reaction. This group of studies assumes that capital flows are exogenously determined. Hassan et al. (2013) used the equation to measure sterilization coefficients.

The second group used a VAR model to estimate the lagged effects of NDAs and NFAs in the following forms:

$$\Delta NDA_t = \alpha_{10} + \sum_{i=1}^{k} \alpha_{1i} \Delta NDA_{t-i} + \sum_{i=1}^{k} \beta_{1i} \Delta NFA_{t-i} + e_{1t}, \tag{2}$$

$$\Delta NFA_t = \alpha_{20} + \sum_{i=1}^{k} \alpha_{2i} \Delta NFA_{t-i} + \sum_{i=1}^{k} \beta_{2i} \Delta NDA_{t-i} + e_{2t}. \tag{3}$$

The important limitation of this approach is that all variables are treated as endogenous and that it cannot estimate the contemporaneous effects among the variables.

The third group estimated the contemporaneous relationship between NDAs and NFAs using a set of simultaneous equations. It is noted that domestic monetary conditions are altered by changes in international capital flows and foreign reserves. And, at the same time, international capital flows respond to a change in domestic monetary conditions. The simultaneous equations are specified as:

$$\Delta NFA_t = \alpha_{10} + \alpha_{11} \Delta NDA_t + X_1 \beta_1 + u_{1t}, \tag{4}$$

$$\Delta NDA_t = \alpha_{20} + \alpha_{21}\Delta NFA_t + X_2\beta_2 + u_{2t}, \quad (5)$$

where X_1 and X_2 are the vectors of controls in the respective functions. Eqs.(4) and (5) are the balance of payments and the monetary reaction functions, respectively. The coefficient α_{11} represents the offset coefficient which is bounded by 0 during no capital mobility stage and -1 when capital mobility is perfect. The coefficient α_{21} represents the sterilization coefficient with -1 representing perfect sterilization of reserve buildup and 0 meaning no sterilization of the centra bank. Brismiss et al. (2002), Ouyang et al. (2008), Ouyang et al. (2010) used the third group of the estimation to derive the two coefficients. This study uses this method.

3. METHODOLOGY AND DATA

Although Ouyang et al. (2010) is the only study that contains Korea as a sample country, most of the papers that I have referred to apply the identical method to derive sterilization and offset coefficients. Ouyang et al. (2008), and Ouyang and Rajan (2011) followed the same method while Wang et al. (2019) applied a slight modification. They followed a modified BGT model (Brissmis et al., 2002) in which the study has used the similar framework of the method, where the simultaneous equations are derived from the minimization of a loss function of the monetary authority. Thereby, the variables used on the baseline equations for these studies are almost identical.

3.1. Methodology

I estimate the sterilization and offset coefficients using the model based on the following literatures: Ouyang et al. (2008), Ouyang et al. (2010), Ouyang and Rajan (2011) and Ouyang et al. (2008). For this study, I mostly follow Ouyang et al. (2010) closely.

Using the framework of simultaneous equations from Ouyang et al (2008), I estimate offset and sterilization coefficients for Korea in the following form:

$$\begin{aligned}\Delta NFA_t = \ & \alpha_0 + \sum \alpha_{1i}\Delta NDA_{t-i} + \sum \alpha_{2i}\Delta mm_{t-i} + \sum \alpha_{3i}\Delta p_{t-i} + \sum \alpha_{4i}\Delta Y_{c,t-i} \\ & + \sum \alpha_{5i}\Delta G_{t-i} + \sum \alpha_{6i}\Delta REER_{t-i} + \sum \alpha_{7i}\Delta(r^*_{t-i} + E_t e_{t+1-i}) + \varepsilon_t, \quad (6)\end{aligned}$$

$$\begin{aligned}\Delta NDA_t = \ & \beta_0 + \sum \beta_{1i}\Delta NFA_{t-i} + \sum \beta_{2i}\Delta mm_{t-i} + \sum \beta_{3i}\Delta p_{t-i} + \sum \beta_{4i}\Delta Y_{c,t-i} \\ & + \sum \beta_{5i}\Delta G_{t-i} + \sum \beta_{6i}\Delta REER_{t-i} + \sum \beta_{7i}\Delta(r^*_{t-i} + E_t e_{t+1-i}) + v_t, \quad (7)\end{aligned}$$

where ΔNFA_t is the annualized monthly/quarterly change in the adjusted net foreign assets scaled by the GDP; ΔNDA_{t-i} is the annualized monthly/quarterly change in the adjusted net domestic asset scaled by the GDP; Δmm_t is the annualized monthly/quarterly change in money multiplier for M2; Δp_t is the annualized monthly/quarterly change in consumer price index; $\Delta Y_{c,t}$ is cyclical income;[4] ΔG_t is cyclical fiscal balance scaled by GDP; $\Delta REER_t$ is the annualized monthly/quarterly change in the real effective exchange rate; $\Delta(r_t + E_t e_{t+1})$ is the annualized monthly/quarterly change in foreign interest rate plus the expected nominal exchange rate (KRW/US$; e_t = Nominal exchange rate (KRW per US$).[5] While the interest rate is used as the indicator of monetary policy in the Taylor rule, the money supply is USED as the indicator in the sterilization studies.

The balance of payment function is represented by Eq(6) and the monetary policy function is illustrated by Eq(7). The coefficient $\sum \alpha_1$ is the offset coefficient and coefficient $\sum \beta_1$ is the sterilization coefficient respectively.

Variables in the equations are explained in the following section.

3.2. Data and Variables

The data are based on monthly data ranging from 1990M1(Q1) to 2020M12(Q4). The data are obtained from IMF IFS (Exchange rate, NFA, GDP) and the BOK ECOS (Monetary base, international reserves, M2). Fiscal balance is obtained from KOSIS (Korean Statistical Information Service) and RGDP (Real GDP) is obtained from FRED (Federal Reserve Economic Data). Table 1 explains the definitions and sources of the data. For cyclical income, industrial production is used to measure real output.

Table 1. Definitions and Measurement of the Variables Used in Empirical Study

Variables	Definitions	Measurement	Data Source
NFA_t	Foreign reserves denominated in domestic currency minus official foreign liabilities	Reserve ($) × e_t – Foreign Liabilities	IFS
ΔNFA_t	The monthly annual change in NFA_t without revaluation effect scaled by the GDP.	$\Delta NFA_t^* = \frac{NFA_t - NFA_{t-12}(e_t/e_{t-12})}{GDP_t}$	IFS
ΔNDA_t	The monthly annual change in (net domestic assets + net other assets – capital item) + revaluation effect scaled by the GDP	$\frac{\Delta NDA_t + \Delta NOA_t + \Delta K_t + \Delta NFA_{t-12}(e_t/e_{t-12})}{GDP_t}$.	IFS
mm_t	Money multiplier for M2	M2/Monetary base	BOK ECOS

[4] On data section (2.2.4.), the cyclical adjustment of income is estimated and the differences or similarities of the income estimation from the Taylor rule is explained.

Table 1. Definitions and Measurement of the Variables Used in Empirical Study (cont')

Variables	Definitions	Measurement	Data Source
Δmm_t	The monthly annual change in money multiplier for M2	$\log(mm_t) - \log(mm_{t-12})$	BOK ECOS
$\Delta REER_t$	The monthly annual change in the real effective exchange rate ($REER$)	$REER_t) - \log(REER_{t-12})$	IFS
$Y_{c,t}$	Cyclical income. The real output deviated from its trend scaled by the trend. The trend is measured by HP filter trend.	$\frac{\log(real\ GDP) - HP\ filter\ trend}{HP\ filter\ trend}$	IFS and FRED
Δp_t	Inflation rate (CPI annual percentage change)	$\log(CPI_t) - \log(CPI_{t-12})$	BOK ECOS
$r_t + E_t e_{t+1})$	The monthly annual change in exchange rate adjusted foreign interest rate. The foreign interest rate is the interest rate for US 3-month treasury bill. $F_{3\text{-}month}$ is the 3-month non-deliverable KRW forward rate.	$\Delta(r_t + \ln e_{t+1})$ if perfect foresight $\Delta(r_t + \ln F_{3-month})$ if forward-looking $\Delta(r_t + \ln e_t)$ if static expectations	IFS
ΔG_t	The fiscal deficit deviated from its trend scaled by the GDP. The trend is measured by HP filter.	$\frac{G_t - HP\ filter\ trend}{GDP_t}$	KOSIS

3.3. Time Period, Subsamples from Structural Breaks

For this study, the estimations are based on the sample period from 1990M1(Q1) to 2021M12(Q4). A version that takes the whole period that does not take out major financial crises (the Global Financial Crisis) will be tested. Besides the whole period, I also use breaks for the estimation. All the breaks and subsamples used for the Taylor rule are applied in the same manner for sterilization studies. Equivalent to the Taylor rule, the global financial crisis during 2008 is used as breaks.

To account for the crises and other structural breaks in the sample, I add dummy variables or drop the crises periods out of the estimates.

3.4. Other Issues

Stationarity is checked for the variables. There should generally be deviations from targets or change.

The use of one period lags in exchange rate (REER), cyclical output, inflation and government spending variables reduces the possible endogeneity problems.

It will be important to take the interest earnings of international reserves into account because the interest earnings would, ceteris paribus, lead to an upward trend in reserves even with no intervention. Creating the variable using the US 3-month Treasury bill rate will help.

4. RESULTS

Table 2 illustrates the results of the simultaneous equations (Eq(8) and (9)) which estimate sterilization and offset coefficients using monthly data. I focus on the monthly data because the monthly data seems to grasp more consistent and credible results than the quarterly data because they go along with the BOK's monthly monetary policy reports. Due to unavailability of the forecast data to achieve forward-looking perspective model, perfect foresight perspective has been adopted for the test because perfect foresight seems to be the best alternative to forward-looking model.

The sterilization coefficients have stayed around -1.0, before and after the crisis, showing that the BOK has sterilized its reserve accumulations heavily throughout the crisis. Almost full sterilization means that the BOK was able to sterilize most of its interventions in the exchange market. Accordingly, the conclusion from the chapter regarding the Combined Propensities to Intervene, in my previous study (Koo, 2024), makes sense. Specifically, it seems reasonable that the persistent intervention policy may have bolstered the link between the US interest rate and Korean monetary policy by limiting the decrease of the exchange rate and its impact on Korean monetary policy.

The offset coefficients have also stayed close to -1.00, before and after the crisis. In principle, the offset coefficient should reflect the degree of capita flow mobility. So, the offset coefficients close to -1 should imply very high freedom in capital flow mobility. However, the offset coefficients of almost -1.0, as a measure of capital mobility, during both periods are misleading and overstated because perfect sterilization occurs only when capital mobility is imperfect. Instead of the offset coefficient, US interest rate coefficient from simple interest rate passthrough model (without the interest rate smoothing coefficient) will be considered as a measure for capital mobility. According to the simple interest rate passthrough model, US interest rate coefficients are statistically significant and are about 0.5 for both quarterly and monthly data. For the model with subperiods, US interest rate coefficients are significant and are about 0.3 during pre-crisis period, while the coefficients are significant and are about -0.4 during post-crisis period. Regardless of being positive or negative, the absolute magnitude of the coefficients between 0.3 and 0.5 indicate that capital mobility in Korea has been far from perfect, but has been fairly open to foreign influences.

As a main variable of interest, the coefficients on exchange rate expectations adjusted foreign interest rate, the coefficients are statistically significant and negative with a very small magnitude, which is -0.001, in both functions (the balance of payment function and the monetary policy function) and for both subperiods (the precrisis and postcrisis periods): The coefficient, -0.001, means that one percent increase of the annual US T-bill rate (adjusted for the annual change in the monthly expected exchange rate) decrease the annual change in NFA by -0.001 billion won (the balance of payment function) and decrease the annual change in NDA by -0.001 won (the monetary policy function). The very small magnitudes of the coefficient indicate that there is no substantial effect of the US interest rate on the balance of payment and on the monetary policy of Korea.

Table 2. Korea: Estimated Simultaneous Equations, Monthly, 1989:M1 – 2007:M11 and 2009:M7 - 2020:M12, Perfect Foresight

	Perfect foresight			
	1989:M1-2007:M11		2009:M7- 2020:M12	
2SLS	ΔNFA_t	ΔNDA_t	ΔNFA_t	ΔNDA_t
ΔNDA_t (offset)	-0.940*** (0.007)	—	-0.981*** (0.005)	—
ΔNFA_t (sterilization)	—	-1.061*** (0.008)	—	-1.016*** (0.005)
Δmm_{t-1}	-0.032*** (0.003)	-0.034*** (0.003)	-0.037*** (0.005)	-0.040*** (0.005)
Δp_{t-1}	-0.024 (0.015)	-0.028* (0.016)	-0.150*** (0.014)	-0.152*** (0.014)
$Y_{c,t-1}$	0.001* (0.002)	0.001* (0.002)	0.000 (0.001)	-0.001 (0.001)
$\Delta REER_{t-1}$	0.008*** (0.002)	0.008*** (0.002)	-0.007*** (0.002)	-0.007*** (0.002)
ΔG_{t-1}	-0.002 (0.008)	0.0001 (0.008)	0.035** (0.016)	0.034** (0.016)
$\Delta(r_t + E_t e_{t+1})$	-0.001*** (0.0001)	-0.001*** (0.0001)	-0.001*** (0.0002)	-0.001*** (0.0002)
Adj. R^2	0.999	0.999	0.997	0.998

Notes: Standard errors are in parenthesis. The asterisks denote statistical significance at the 1(***), 5(**), and 10(*) per cent levels.

The result confirms that there are consistent, yet weak, ties between US interest rate and Korean monetary policy which is parallel with the results from the Taylor rule equations.[6] This is expected because higher exchange adjusted US interest rate can lead to capital outflows and consequent reduction of reserve build-up (the balance of payment function) and the worsened balance of payment can lead the monetary authority to implement a contractionary monetary policy to attract capital inflows (the monetary policy function).

The coefficients on the exchange rate variable (real effective exchange rate) are statistically significant and positive with a small magnitude, equaling 0.008, before the crisis meaning that one unit increase of the annual change in REER (devaluation of won against US dollar) is associated with an increase of the annual change in NFA by 0.008 billion won (the balance of payment function) and is associated with an increase of the annual change in NDA by 0.008 billion won (the monetary policy function). However, the exchange rate coefficients are statistically significant and negative with a small economic significance, equaling -0.007, after the crisis meaning that one unit increase of the annual change in REER (devaluation of won against US dollar) is associated with a decrease of the annual change in NFA by 0.007 billion won (the balance of payment function) and is associated with an decrease of the annual change in NDA by 0.007 billion won (the monetary policy function). The very small magnitude of the coefficient indicates that it is not economically significant. However, the magnitude of the exchange rate variable is seven (or eight) times larger than the magnitude of the (exchange adjusted) foreign interest rate. This is very similar to the result from the Taylor rule study. For the postcrisis model on Table 2 (Koo, 2024), the magnitude of the exchange rate variable is also seven (or eight) times larger than the magnitude of the US interest rate. The precrisis model in Table 1 (Koo, 2024) does not have a significant exchange rate variable, but its coefficient has a magnitude which is five (or six) times larger than the magnitude of the US interest rate. So, the exchange rate variable definitely has much higher economic significance than the US interest rate variable on Korean monetary policy (for the Taylor rule and the monetary policy function) and on the balance of payment (the balance of payment function).

The positive coefficient of the exchange variable before the crisis can be explained by the volume effect of the elasticity approach to the balance of payments. The rise of the REER (devaluation of won) will lead to the improvement of the current account (due to the volume effect), consequent accumulation of reserves (for the balance of payment function) and the improved balance of payment will cause the monetary authority to implement expansionary monetary policy to resist further capital inflows (for the monetary policy function). For won devaluation (the exchange rate increase) to bring on the improvement of the balance of payments, the Marshall-Lerner condition has to be satisfied for the volume effect has to dominate the price effect.[7] Korea has had very

[6] The results are shown on Table 1-2 from Koo (2024).

[7] According to the Marshall-Lerner condition, a devaluation will improve the current account only if the sum of the foreign elasticity of demand for exports and the home country elastic of demand for imports is greater than unity.

high elasticity of demand of exports as an export-driven economy and many study show that the Marshall-Lerner condition was fulfilled for Korea.[8]

The positive coefficient of the exchange rate for the precrisis period contrasts with the result from the Taylor rule study. On the Taylor rule study for the precrisis period, Table 1 (Koo, 2024), won depreciation causes the Korean policy rate to increase. The distinction between the two results is found from the difference in the response variables. While the change in NFA (the balance of payment) and the change in NDA (the monetary policy regarding the money supply) are responsive to the variation of money supply, Korean policy rate decisions are based on the monthly monetary policy reports and the meeting of the BOK. So, the decision of the policy rate is not dependent solely on a single indicator.

The policy rate increases in response to won depreciation for the Taylor rule study may have nothing to do with the improved balance of payments. The decision seems to be mainly affected by the concerns regarding the low level of reserves amidst the aftermath of the AFC (Kim and Lee, 2011). As can be observed from the reserve levels on Table 12, they are relatively low up to the point of GFC. And there could have been concerns regarding the balance of payment collapse because of the J-curve effect: Won depreciation will initially bring on the balance of payment to worsen. So, the newly deteriorated balance of payment along with low reserve levels could have sent warning signs to Korean monetary authority.

On the contrary, the negative coefficient of the exchange variable after the crisis can be explained by the active exchange rate policy: An appreciation of won (a fall in the REER) will likely lead the BOK to engage in intervention policy accumulating reserves to limit the appreciation (the balance of payment function) and the improved balance of payment will lead to an expansionary monetary policy to restrain further capital inflows (the monetary policy function). The results from my previous study (Koo, 2024) explained that there have been heavy interventions countering the exchange rate movements after the GFC. Also, it is notable that the heavy (almost perfect) sterilization made it possible for the BOK to engage in aggressive intervention policy.[9]

Again, the negative coefficient of the exchange rate variable during the postcrisis period tells a different story from the result of the Taylor rule study. Won appreciation brings on the policy rate increase for the Taylor rule study of the postcrisis period. The deciding factor for the result is the status of the domestic economy. Sustained economy growth will bring about won appreciation and, consequently, the policy rate increase of the BOK. It goes the other way too. An economic slowdown will cause won to depreciate and the policy rate to decrease.

[8] Gylfason (1987), with a sample period of 1969-1981, Giorgianni and Milesti-Ferretti (1997), with a sample period of 1971-1989, Kee et al. (2008), with a sample period of 1988-2001, and Bahmani-Oskooee and Baek (2015), with a sample period of 1991-2012.

[9] Chapter VII from Koo (2024) shows the results of the study regarding the combined propensities to intervene (CPI).

Thus, the findings regarding the exchange rate from the Sterilization model also contradict the theory by Rey (2015) that exchange rate does not play a role in pursuing an independent monetary policy. The exchange rate coefficients are statistically significant across all periods and functions, while the economic significance is not substantial. So, there is a steady, yet weak, link between the exchange rate and monetary policy regarding the money supply. In addition, the different effects the exchange rate has on the balance of payments and the monetary policy (mostly open market operations) before and after the GFC reveals the different focus of the monetary policy around the crisis. Active intervention policy to manage exchange rates after the crisis has affected the balance of payments and the direction of monetary policy.

Domestic policy variables contain varying results. The coefficients on the fiscal policy variable are statistically significant and positive with a small magnitude, equaling 0.035, after the crisis, meaning that one billion won increase of the annual change of fiscal balance is associated with an increase of the annual change in NFA by 0.035 billion won (the balance of payment function) and is associated with an increase of the annual change in NDA by 0.035 billion won (the monetary policy function). The magnitude of the coefficient is small meaning that it is not economically meaningful.

The coefficients on the money multiplier are statistically significant, with a small magnitude, and negative across all criteria ,equaling -0.03 ~ -0.04, meaning that one unit increase of the annual change in money multiplier is associated with a decrease of the annual change in NFA by 0.03 billion won for the balance of payment function (and a decrease of the annual change in NDA by 0.03 billion won for the monetary policy function). This is expected because the rise in the money multiplier increases the domestic money supply and pushes interest rates down, reducing the capital inflows and reserve build-up, which would lead to a contractionary monetary policy. Although, the magnitudes of the coefficient are quite small (-0.03 ~ -0.04), they are much larger than the ones of the foreign interest rate coefficient (-0.001) and the exchange rate coefficient (0.008 and -0.007).

The coefficients on inflation are statistically significant and negative with decent magnitudes, during the postcrisis period, at -0.15 meaning that one percent increase of the annual change in the inflation rate is associated with a decrease of the annual change in NFA by 0.15 billion won for the balance of payment function (and a decrease of the annual change in NDA by 0.15 billion won for the monetary policy function). The negative coefficients are anticipated because higher inflation can generate concerns regarding exchange rate depreciation, interest rate hikes and capital losses, causing a reduction of reserve accumulation and a contractionary monetary policy. However, the effects of inflation are pronounced after the crisis as the coefficients are statistically significant (at 1%) and have larger magnitude (in absolute terms) during the postcrisis period. Much larger magnitude of the inflation coefficient (0.15) and money multiplied coefficient (-0.03) compared to the magnitude of the foreign interest rate (-0.001) and the exchange rate (0.008) can indicate that the impact of the inflation targeting and money supply is much more pronounced than the impact of the US interest rate or the exchange rate policy on Korean monetary policy or on its balance of payment during the postcrisis period.

Finally, the results from the output coefficients from this monthly data are inconclusive. The coefficients on the output before the crisis are statistically significant, and positive with a miniscule magnitude, 1.0e-07, while the coefficients, after crisis, are not significant and negative. Basically, the output gap brings no substantial change in Korean monetary policy or on its balance of payment.

To sum up, highly statistically significant sterilization coefficients at around -1 suggest that the BOK has heavily (almost perfectly sterilized its reserve accumulation (along with the interventions in the exchange market) throughout from 1990s. The estimated offset coefficients close to -1.0, which is statistically significant, are vastly overstated and ambiguous. The degree of capital mobility is represented better by the US interest rate coefficient from the simple interest rate passthrough model. The coefficient between 0.3 and 0.5 show a moderate degree of capital mobility and a degree of Korea's capital control.

The exchange rate adjusted foreign interest rate is statistically significant across all the estimations with the correct sign (at -0.001), albeit with not being economically meaningful. This demonstrates that there is a consistent, but not substantial, link between the US interest rate and Korean monetary policy.

The exchange rate coefficient indicates a different effect around the crisis. The coefficients, before the crisis, are statistically significant and positive with very small magnitude (at 0.008), while the coefficients, after the crisis, are negative and statistically significant with still very small magnitude (at -0.007). The coefficients show steady, but weak, links between the exchange rate and the balance of payments/monetary policy (open market operations). The different directions of the coefficients before and after the crisis indicate that the monetary authority has actively managed the exchange rate through intervention after the crisis. Comparing with how the exchange rate affects the monetary policy with the Taylor rule models, it is found that the different direction of the policy is due to the kind of monetary policy tools that is used. Since the policy rate changes focus on different criteria from open market operations, the monetary policy directions caused by exchange rate changes can differ between the Taylor rule models and the Sterilization/Offset studies. Above all, the results strongly refute Rey's (2015) theory of 'Dilemma not Trilemma' by emphasizing the importance of role of exchange rate on its impact on the monetary policy.

The coefficients on the money multiplier are statistically significant, with a small magnitude, and negative across all criteria, equaling -0.03 ~ -0.04. The inflation rate coefficients are statistically significant and negative with a fair magnitude during the postcrisis period, at -0.15. As can be seen from the larger magnitudes of the coefficients, the variables regarding domestic economy (inflation rate, money multiplier) have more substantial impact on the monetary policy (open market operations) than the variables concerning the international economy (US interest rate, exchange rate). Also, the stronger impact of the inflation rate variable during the postcrisis period is in agreement with the results from the Taylor rule model. However, the results from the output coefficients, which have very miniscule value of coefficients, show that the output has almost no impact on the balance of payments and the monetary policy. Finally, the coefficients on government spending are statistically significant and positive with a small magnitude, equaling 0.035, after the crisis.

Robustness Checks

A number of robustness checks have been performed. First, 3SLS (three-stage least squares) estimation methods have been used to check the results in addition to 2SLS (two-stage least squares) method (Table 3). Second, static expectation perspective model has been tested instead of perfect foresight view (Table 4). Third, other kinds of filters, such as Baxter-King (BK; Table 5), Butterworth (BW; Table 6), Christiano-Fitzerald (CF; Table 7), have been tested due to problems with Hodrick-Prescott (HP) filter. As can be confirmed from the results on the tables, the regression results are robust across all cases.

Table 3. Korea: Estimated Simultaneous Equations, Monthly, 1989:M1 – 2007:M11 and 2009:M7 - 2020:M12, Perfect Foresight, 3SLS

	Perfect foresight			
	1989: M1-2007: M11		2009: M7- 2020: M12	
3SLS	ΔNFA_t	ΔNDA_t	ΔNFA_t	ΔNDA_t
ΔNDA_t (offset)	-0.940*** (0.007)	—	-0.981*** (0.005)	—
ΔNFA_t (sterilization)	—	-1.061*** (0.007)	—	-1.016*** (0.005)
Δmm_{t-1}	-0.032*** (0.002)	-0.034*** (0.003)	-0.037*** (0.005)	-0.040*** (0.005)
Δp_{t-1}	-0.024 (0.014)	-0.028* (0.015)	-0.150*** (0.013)	-0.152*** (0.014)
$Y_{c,t-1}$	0.001* (0.002)	0.001* (0.002)	0.000 (0.001)	-0.001 (0.001)
$\Delta REER_{t-1}$	0.008*** (0.001)	0.008*** (0.002)	-0.007*** (0.002)	-0.007*** (0.002)
ΔG_{t-1}	-0.002 (0.007)	0.000 (0.008)	0.035** (0.015)	0.034** (0.015)
$\Delta(r_t + E_t e_{t+1})$	-0.001*** (0.000)	-0.001*** (0.000)	-0.001*** (0.000)	-0.001*** (0.000)
Adj. R^2	0.999	0.999	0.997	0.998

Notes: Standard errors are in parenthesis. The asterisks denote statistical significance at the 1(***), 5(**), and 10(*) per cent levels.

Table 4. Korea: Estimated Simultaneous Equations, Monthly, 1989:M1 – 2007:M11 and 2009:M7 - 2020:M12, Static Expectation

	Static expectation			
	1989:M1-2007:M11		2009:M7- 2020:M12	
2SLS	ΔNFA_t	ΔNDA_t	ΔNFA_t	ΔNDA_t
ΔNDA_t (offset)	-0.940*** (0.007)	—	-0.981*** (0.005)	—
ΔNFA_t (sterilization)	—	-1.061*** (0.008)	—	-1.016*** (0.005)
Δmm_{t-1}	-0.032*** (0.003)	-0.034*** (0.003)	-0.038*** (0.005)	-0.040*** (0.005)
Δp_{t-1}	-0.023 (0.015)	-0.027* (0.016)	-0.150*** (0.014)	-0.153*** (0.014)
$Y_{c,t-1}$	0.003* (0.002)	0.001* (0.002)	0.000 (0.001)	-0.001 (0.001)
$\Delta REER_{t-1}$	0.008*** (0.002)	0.008*** (0.002)	-0.006*** (0.002)	-0.007*** (0.002)
ΔG_{t-1}	-0.002 (0.008)	-0.0002 (0.008)	0.035** (0.015)	0.035** (0.016)
$\Delta(r_t + E_t e_{t+1})$	-0.001*** (0.0001)	-0.001*** (0.0001)	-0.001*** (0.0002)	-0.001*** (0.0002)
Adj. R^2	0.999	0.999	0.997	0.998

Notes: Standard errors are in parenthesis. The asterisks denote statistical significance at the 1(***), 5(**), and 10(*) per cent levels.

Table 5. Korea: Estimated Simultaneous Equations, Monthly, 1989:M1 – 2007:M11 and 2009:M7 - 2020:M12, Perfect Foresight, Using BK Filter

	Perfect foresight			
	1989:M1-2007:M11		2009:M7- 2020:M12	
2SLS	ΔNFA_t	ΔNDA_t	ΔNFA_t	ΔNDA_t
ΔNDA_t (offset)	-0.940*** (0.007)	—	-1.029*** (0.005)	—
ΔNFA_t (sterilization)	—	-1.063*** (0.008)	—	-0.969*** (0.004)
Δmm_{t-1}	-0.031*** (0.003)	-0.033*** (0.003)	-0.052*** (0.003)	-0.051*** (0.003)
Δp_{t-1}	-0.022 (0.015)	-0.026 (0.016)	-0.115*** (0.008)	-0.111*** (0.007)
$Y_{c,t-1}$	-0.001 (0.001)	0.000 (0.001)	0.000 (0.001)	0.000 (0.001)
$\Delta REER_{t-1}$	0.008*** (0.002)	0.009*** (0.002)	-0.012*** (0.001)	-0.012*** (0.001)
ΔG_{t-1}	-0.002 (0.008)	0.0001 (0.009)	0.038** (0.008)	0.037** (0.008)
$\Delta(r_t + E_t e_{t+1})$	-0.001*** (0.000)	-0.001*** (0.000)	0.001*** (0.000)	-0.001*** (0.000)
Adj. R^2	0.999	0.999	0.999	0.999

Notes: Standard errors are in parenthesis. The asterisks denote statistical significance at the 1(***), 5(**), and 10(*) per cent levels.

Table 6. Korea: Estimated Simultaneous Equations, Monthly, 1989:M1 – 2007:M11 and 2009:M7 - 2020:M12, Perfect Foresight, Using BW Filter

	Perfect foresight			
	1989:M1-2007:M11		2009:M7- 2020:M12	
2SLS	ΔNFA_t	ΔNDA_t	ΔNFA_t	ΔNDA_t
ΔNDA_t (offset)	-0.940*** (0.007)	—	-0.981*** (0.005)	—
ΔNFA_t (sterilization)	—	-1.063*** (0.008)	—	-1.016*** (0.005)
Δmm_{t-1}	-0.031*** (0.003)	-0.033*** (0.003)	-0.037*** (0.005)	-0.039*** (0.005)
Δp_{t-1}	-0.022 (0.015)	-0.026 (0.016)	-0.150*** (0.014)	-0.151*** (0.014)
$Y_{c,t-1}$	0.000 (0.001)	0.000 (0.001)	0.001** (0.001)	0.001** (0.001)
$\Delta REER_{t-1}$	0.008*** (0.002)	0.009*** (0.002)	-0.006*** (0.002)	-0.007*** (0.002)
ΔG_{t-1}	-0.003 (0.008)	-0.001 (0.008)	0.033** (0.015)	0.033** (0.016)
$\Delta(r_t + E_t e_{t+1})$	-0.001*** (0.0001)	-0.001*** (0.000)	-0.001*** (0.000)	-0.001*** (0.000)
Adj. R^2	0.999	0.999	0.997	0.998

Notes: Standard errors are in parenthesis. The asterisks denote statistical significance at the 1(***), 5(**), and 10(*) per cent levels.

Table 7. Korea: Estimated Simultaneous Equations, Monthly, 1989:M1 – 2007:M11 and 2009:M7 - 2020:M12, Perfect Foresight, Using CF Filter

	Perfect foresight			
	1989:M1-2007:M11		2009:M7- 2020:M12	
2SLS	ΔNFA_t	ΔNDA_t	ΔNFA_t	ΔNDA_t
ΔNDA_t (offset)	-0.940*** (0.007)	—	-0.981*** (0.005)	—
ΔNFA_t (sterilization)	—	-1.062*** (0.008)	—	-1.016*** (0.005)
Δmm_{t-1}	-0.031*** (0.003)	-0.033*** (0.003)	-0.037*** (0.005)	-0.040*** (0.005)
Δp_{t-1}	-0.024 (0.015)	-0.028* (0.016)	-0.150*** (0.014)	-0.152*** (0.014)
$Y_{c,t-1}$	0.000* (0.001)	-0.001 (0.001)	-0.001 (0.001)	-0.001 (0.001)
$\Delta REER_{t-1}$	0.008*** (0.002)	0.009*** (0.002)	-0.007*** (0.002)	-0.007*** (0.002)
ΔG_{t-1}	-0.003 (0.008)	-0.001 (0.008)	0.034** (0.015)	0.034** (0.016)
$\Delta(r_t + E_t e_{t+1})$	-0.001*** (0.000)	-0.001*** (0.000)	-0.001*** (0.000)	-0.001*** (0.000)
Adj. R^2	0.999	0.999	0.997	0.998

Notes: Standard errors are in parenthesis. The asterisks denote statistical significance at the 1(***), 5(**), and 10(*) per cent levels.

5. CONCLUSION

Analyzing the two main monetary policy tools interest rates and the money supply, controlling for various variables, in the form of the Taylor rule and the sterilization/offset study, I examined the effect of the US influences on Korean monetary policy in a refined way. Two types of external influences on Korean monetary policy have been analyzed: The US interest rate and the fluctuations in the exchange rate (won against the US dollar). Regarding Korean monetary policy, I have examined the following two types of monetary policy tools: Korean policy rate and the monetary policy concerning the money supply in Korea. The Taylor rule study examined external influences on the Korean policy rate, while the Sterilization/Offset study analyzed the effects of balance of payments imbalances on the money supply.

The empirical test results for the Sterilization/Offset study showed almost perfect sterilization coefficients throughout the whole period (which are about -1.0) which suggested that the BOK has completely sterilized its reserve accumulation and the intervention in the exchange market from 1990s.[10] However, the offset coefficients, of almost -1.0, during both periods were misleading and overstated because perfect sterilization occurs only when capital mobility is imperfect. Instead of the offset coefficient, US interest rate coefficient from simple interest rate passthrough model (Table 15) was considered as a measure for capital mobility. The US interest rate coefficients between 0.3 and 0.5 showed a moderate degree of capital mobility.

US interest rate (exchange rate adjusted) coefficients reflect steady, but economically weak, link between the US interest rate and Korean monetary policy. High US interest rate, causing a worsening of the balance of payments, tends to lead to a contractionary monetary policy of the BOK to attract capital inflows. This result is consistent with the results from the Taylor rule study.[11]

The exchange rate coefficients also reveal steady, yet weak, link between the exchange rate and Korean monetary policy. However, the economic significance of the exchange rate coefficients, which is not substantial, are about seven to eight times larger than the ones from the US interest rate coefficients (This is very similar to the results of the Taylor rule study).

Another feature of the coefficient is that the direction of Korean monetary policy in response to the exchange rate differs before and after the GFC. Before the crisis, the exchange rate increase (devaluation of won) leads to an improvement of the balance of

[10] Regarding the influence that I have tested with the sterilization coefficients in terms of the effects on the money supply, the balance of payments employed are the overall or official settlements balance which corresponds to changes in international reserves.

[11] US interest rate coefficients on the Taylor rule study (Koo, 2024) are statistically significant and economically not significant throughout most specifications. The positive coefficient implies that US interest rate hike tends to cause a contractionary monetary policy of the BOK.

payments (through volume effect), leading to an expansionary monetary policy. This makes sense because Korea has shown very high elasticity of demand of exports which causes the volume effect to overshadow the price effect. The Taylor rule study shows different result: During the precrisis period, the exchange rate increase leads to a contractionary monetary policy of the BOK. The different results between the two studies can be traced to the difference in the response variables. The changes regarding the balance of payment and the consequent monetary policy, on the Sterilization and Offset study, are based on the flow of money supply. However, Korean policy rate decisions, from the Taylor rule study, are coming from more intricacies as the BOK officials make the decisions from the monthly meetings. The policy rate increases seem to be mainly caused by the low reserve levels after the AFC.

After the crisis, a fall in the exchange rate (won appreciation) leads to an expansionary monetary policy of the BOK because active intervention policies to counter won appreciation cause build-up of reserves, improving the balance of payment. Almost perfect sterilization after the GFC indicates that the BOK has implemented heavy intervention policy then. The Taylor rule study brings contrasting results again: During the postcrisis period, the exchange rate decrease leads to a contractionary monetary policy of the BOK. The BOK is mainly concerned about the status of the domestic economy then. Steady economy growth seems to lead won appreciation and the BOK policy rate increase.

Regarding domestic economy variables, money multiplier coefficients and inflation coefficients carry expected negative signs while being statistically significant. However, output coefficients show that output has almost no impact on Korean monetary policy and fiscal policy coefficients imply that more government spending is associated with expansionary monetary policy after the GFC.

Exchange rate flexibility has allowed Korea's monetary policy to operate with a great deal of independence from the US interest rate. This is consistent with the traditional monetary trilemma analysis and not with Rey's dilemma analysis.

As a country with adjusted pegged exchange regimes, Korea has been susceptible to currency crise.[12] However, sterilized intervention could have cushioned the repercussions from the temporary disturbance on the economy due to currency instability. In fact, sterilization policies can be regarded as appropriate policies for a managed float regimes such as Korea (Willett, 2009) because they will help to maintain exchange rate stability without infringement of national monetary policies.

Sterilized intervention can contribute to exchange rate stability in another way. The negative exchange rate coefficients before the GFC on Table 1 and high combined propensities to intervene after the GFC from my previous study, on Table 5 of Koo (2024), explains that Korea has engaged in active intervention policies after the GFC. Since sterilization enables implementation of intervention policies, sterilized policies are

[12] Providing rationale for the unstable middle hypothesis, adjustable fixed rates are prone to serious time asymmetries (Willett, 2009).

indirectly helping to achieve short-run currency stability.

The test results from the simultaneous equations indicate that the BOK has heavily sterilized throughout all tested periods and that capital mobility has been at a moderate degree which has enabled sterilization policies to be effective.

Almost perfect degree of sterilization, along with the findings above, strengthen the argument that the BOK has been able to implement independent monetary policy. It's because the perfect sterilization implies that Korea's managed float exchange rate has not been a source of discipline over domestic monetary policy (especially over inflation) and, rather, the exchange rate regime has not interfered with the BOK to conduct independent monetary policy (McKinnon and Schnabl, 2003a, 2003b, 2004a, 2004b). Also, the perfect sterilization has enabled the BOK to perform the exchange rate policy (intervention) at will whenever there has been alarming exchange rate appreciation. And crucially it can do this without disturbing domestic monetary policy.

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