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NONLINEAR MONETARY POLICY REACTION WITH ASYMMETRIC CENTRAL BANK PREFERENCES: SOME EVIDENCE FOR KOREA*

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Abstract

The paper considers asymmetric central bank preferences and nonlinear AS curve in the monetary policy reaction function to examine nonlinear property of monetary policy rules. The optimal monetary policy rules are derived in a new Keynesian macroeconomic framework where the central bank has the asymmetric objective function. The derived reaction function explains the nonlinear reaction to the inflation gap and the output gap. The nonlinear reaction function is applied to explain the determination of the interest rate in Korea for the sample period of inflation targeting September 1998 to December 2005. The empirical evidence supports that the objective of the central bank is asymmetric in inflation management. The evidence of asymmetric reaction to the output gap is relatively weak. The empirical analysis reveals that the central bank responds strongly to the positive inflation gap compared to the negative inflation gap.

Key words: Asymmetric Preferences; Inflation Targeting; Monetary Policy; Nonlinear Reaction
JEL classification: E52; E58

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I. *Introduction*

Many studies have investigated the optimal monetary policy or the monetary policy rules under the assumption that the preferences of the central banks are symmetric over key macroeconomic variables such as inflation and output. Usually, they employ the standard linear-quadratic framework, which consists of central bank's quadratic loss function and the linear aggregate supply and demand functions. The quadratic (symmetric) preferences imply that the central bank has weighted the same amount of loss both on positive deviations of inflation or output from the target level and on negative deviations of the same size. This linear-quadratic framework leads to the linear reaction function, known as the Taylor rule, which is the first order condition for optimizing the central bank's objective function.

Recently, a growing number of studies have questioned this quadratic preference assumption. Specifically, is the inflation gap in the negative side as undesirable as that in the positive side of the same amount? Is the output gap in the positive side as distasteful as that in the negative side of the same size? Nobay and Peel (1998, 2003), Ruge-Murcia (2002), Surico (2003a), and Karagedikli and Lees (2004) relax the assumption of the quadratic preferences of the central bank and adopt instead asymmetric preference specifications. The asymmetric loss function generally leads to a nonlinear reaction function or monetary policy rule, which is different from the first order condition for the optimization problem of the central bank with symmetric preferences. Whether the central bank has the asymmetric objective function is an important issue since many of the results on the time inconsistency problem under symmetric preferences may no longer hold under asymmetric preferences as shown in Nobay and Peel (2003), and Surico (2003a).

The preferences of the central bank can be inferred from the monetary policy reaction function. However, as shown by Nobay and Peel (2000), a nonlinear monetary policy reaction function can also be derived from the nonlinear aggregate supply curve. Therefore, Surico (2003b), and Dolado *et al*. (2004) have studied the asymmetric central bank preferences with a nonlinear aggregate supply relationship. They tried to estimate the asymmetric preferences of the central bank controlling the nonlinear component arising from the nonlinear aggregate supply curve.

Most of studies about the asymmetric preferences of the central bank are concentrated on the developed countries. In addition, empirical evidence of nonlinear monetary policy reaction function depends on the countries and the sample period studied. Recently, the way of conducting monetary policy in Korea has changed dramatically. The Bank of Korea Act was revised in April 1998, and since then the inflation targeting has been adopted as a new monetary policy system. In addition, the Bank of Korea (BOK), which is the central bank in Korea, uses the interest rate - the overnight call rate - as its monetary policy instrument instead of monetary aggregates such as reserves and M2. This institutional change has stimulated Taylor-rule type monetary policy analysis. For example, Eichengreen (2004) analyzed the monetary and exchange rate policy of the Bank of Korea by estimating the Taylor type monetary policy rule. The Bank of Korea has set up the explicit inflation targeting since 1998, and thus the study on its asymmetric preferences to inflation is a natural extension of the previous studies, which assumed the quadratic preferences.

The asymmetric preferences of the Bank of Korea are estimated by Kwon (2006) in a model with the linear aggregate supply curve. We allow for nonlinear aggregate supply curve. Also, this paper employs a dynamic specification of the reaction function, which is derived from the central bank's objective function with adjustment costs.

This paper provides an empirical assessment of the monetary policy rules in Korea for the inflation targeting period September 1998 to December 2005. We are trying to answer the question whether the preferences for inflation and output gap of the Bank of Korea are asymmetric. Asymmetric preferences imply that the central bank has a precautionary demand for inflation and for expansions.[1] The central bank may respond more strongly to positive inflation and to negative output gaps. The contribution of this paper is to provide some evidence supporting that the preferences of the central bank may not be symmetric over inflation gap, and therefore it adds another empirical result to the literature of asymmetric preferences of the central bank.

The rest of the paper is organized as follows. Section Ⅱ presents the asymmetric objective function of the central bank in a new Keynesian macroeconomic framework. Under this framework, we derive the monetary reaction function, which serves as a benchmark for the empirical analysis. Section Ⅲ deals with the data. The empirical results are provided in section Ⅳ.

II. *The Model*

1. The Economy

We adopt the new Keynesian framework as an economy in which inflation and output gaps depend on the expected future values of those variables and in which the policy instrument of the central bank is the nominal interest rate. The model of this kind has been popularized for use in the monetary policy literature after Clarida *et al*. (1999), Gali and Gertler (1999), Woodford (1999, 2001), McCallum and Nelson (1999) and Svensson and Woodford (1999, 2003).

The economy can be specified by using the following two-equation system corresponding to the aggregate demand and aggregate supply relations:

$$\tilde{y}_t = E_t\tilde{y}_{t+1} - \alpha(i_t - E_t\pi_{t+1}) + e_t^d, \tag{1}$$

$$\pi_t = \omega E_t\pi_{t+1} + F(\tilde{y}_t) + e_t^s, \tag{2}$$

where

$$F(\tilde{y}_t) = \beta\tilde{y}_t/(1-\beta\psi\tilde{y}_t). \tag{3}$$

In addition, $\tilde{y}_t$ is the output gap and π_t is the inflation rate, $E_t\tilde{y}_{t+1}$ and $E_t\pi_{t+1}$ are the expected values of those variables conditioned on the information available at period t, i_t is the

[1] Cukierman and Muscatelli (2003) call it the situation that the policy makers might respond more aggressively to negative output gaps than to positive ones when they are uncertain the state of the economy.

nominal rate of interest, and $\alpha>0$, $\omega>0$, $\beta>0$ and ψ are parameters. The demand disturbance e_t^d and the supply disturbance e_t^s are assumed to follow a mean reverting process.

Equation (1) is represented by a linear approximation of the Euler condition for optimizing the objective function of the representative household. It basically postulates a forward-looking IS relationship where the output gap depends on the expected output gap and the real interest rate $i_t - E_t\pi_{t+1}$. Equation (2) is derived under the assumption of the monopolistic competition, where individual firms adjust prices in a staggered and overlapping fashion. Also, it is a forward-looking AS relationship where inflation depends on expected inflation and output gap. The relationship between inflation and output gap in equation (2) is represented by a function $F(\tilde{y}_t)$, which is capable of explaining a nonlinear relationship. The nonlinearity in AS curve is specified by equation (3). This functional form is used by Schaling (1999), Surico (2003b), Dolado *et al*. (2004), and Dolado *et al*. (2005) because it can be a linear or nonlinear AS curve depending on the value of the parameter (ψ) representing the degree of nonlinearity. If the parameter is zero ($\psi=0$), then the AS curve turns into the standard linear relation. If the parameter is positive ($\psi>0$), the relation is a nonlinear one as it allows the slope of the aggregate supply curve to be steep. It can be justified by the presence of capacity constraint, menu costs, downward wage rigidity, and the existence of money illusion at very low rates of inflation. The parameter can be negative ($\psi<0$), which implies that the relationship between inflation and output gap is concave.

2. The Central Bank

The central bank minimizes the expected value of the loss function with an instrument of the interest rate.

$$Min_{\{i_t\}}\, E_{t-1}\sum_{j=0}^{\infty}\delta^j V_{t+j}, \tag{4}$$

where δ ($0<\delta<1$) is the discount factor of the central bank and V_t is the period loss function.

The loss function is assumed to take the following linear-exponential (linex) form for inflation and output gap:

$$V_t=\left[\frac{\exp\{\varphi(\pi_t-\pi^*)\}-\varphi(\pi_t-\pi^*)-1}{\varphi^2}\right]+\theta\left[\frac{\exp(\phi\tilde{y}_t)-\phi\tilde{y}_t-1}{\phi^2}\right]+\frac{A}{2}(i_t-i_{t-1})^2, \tag{5}$$

where π^* is the target inflation rate. The parameters θ and A are strictly positive and govern the relative weight that the central bank places on output and interest rate stabilization relative to inflation stabilization, respectively. The parameter φ represents the degree of asymmetry with respect to inflation, while the parameter ϕ stands for that with respect to the output gap.

The linex functional form in equation (5) is frequently used in the recent literature on asymmetric monetary policy rules, including Nobay and Peel (2003), Surico (2003a, 2003b), Ruge-Murcia (2003b) and Karagedikli and Lees (2004). It determines the type of asymmetric preferences that serve as the metric to evaluate alternative monetary policies. Also, the linex functional form nests the quadratic form as a special case. That is, using L'Hopital's rule we can show that the loss function (5) becomes the conventional quadratic loss function[2] as the parameter values of φ and ϕ approach zero

$$V_t = \frac{1}{2}(\pi_t - \pi^*)^2 + \frac{\theta}{2}\tilde{y}_t^2 + \frac{A}{2}(i_t - i_{t-1})^2.$$

If φ is non-zero, then the linex function weighs differently with respect to positive and negative deviations of inflation from the target. For example, if $\varphi > 0$, positive deviations of inflation from the target are more costly than negative ones since the exponential term dominates the linear term in equation (5), while negative deviations of inflation from target are more costly than positive ones because the linear term dominates the exponential term when $\varphi < 0$. In the same way, a non-zero ϕ implies asymmetry in the output gap. If $\phi < 0$, the loss from the negative output gap is more burdensome than that from the positive output gap, while a positive output gap is more costly than a negative one when $\phi > 0$.

The loss function in this paper is different from Surico (2003b) in the sense that we use $(i_t - i_{t-1})^2$ instead of $(i_t - i^*)^2$ where i^* is the target rate. The target interest rate corresponds to the target inflation and the target output gap. As noted by Woodford (1999), there exists monetary policy inertia, which implies strong adjustment costs. As shown in Figure 5, the actual call rate deviates from the target rate and the deviation does not vanish quickly. Surico (2003b) transformed the reaction function considering the partial adjustment behavior of interest rate. In this paper we formally incorporate the partial adjustment process into the period loss function. The same objective function with adjustment costs is considered in Svensson (2000).

3. Monetary Policy Reaction

The monetary authority minimizes the expected loss from the inflation gap and the output gap facing the economy, which can be characterized by the aggregate demand and supply relations. Therefore, the problem of the central bank is to choose the current interest rate and the sequence of future interest rates such as to minimize following function subject to the behavior of the economy:

$$E_{t-1}\left[\frac{\exp\{\varphi(\pi_t - \pi^*)\} - \varphi(\pi_t - \pi^*) - 1}{\varphi^2}\right] + \theta E_{t-1}\left[\frac{\exp(\phi\tilde{y}_t) - \phi\tilde{y}_t - 1}{\phi^2}\right]$$
$$+ \frac{A}{2}(i_t - i_{t-1})^2 + \frac{\delta A}{2}E_{t-1}(i_{t+1} - i_t)^2 + S_t \tag{6}$$

subject to

$$\tilde{y}_t = -\alpha i_t + f_t, \tag{7}$$

$$\pi_t = \beta\tilde{y}_t / (1 - \beta\psi\tilde{y}_t) + g_t, \tag{8}$$

where $S_t \equiv E_{t-1}\sum_{j=2}^{\infty}\delta^j V_{t+j}$, $f_t \equiv E_t\tilde{y}_{t+1} + \alpha E_t\pi_{t+1} + e_t^d$ and $g_t \equiv \omega E_t\pi_{t+1} + e_t^s$.

[2] For example, $\lim_{\phi \to 0}\frac{\exp(\phi\tilde{y}_t) - \phi\tilde{y}_t - 1}{\phi^2} = \lim_{\phi \to 0}\frac{\tilde{y}_t\exp(\phi\tilde{y}_t) - \tilde{y}_t}{2\phi} = \lim_{\phi \to 0}\frac{\tilde{y}_t^2\exp(\phi\tilde{y}_t)}{2} = \frac{\tilde{y}_t^2}{2}$

The first order condition (FOC) for minimizing the objective function of the central bank is given by

$$-E_{t-1}\left[\frac{\exp\{\varphi(\pi_t-\pi^*)\}-1}{\varphi}\right]\frac{\alpha\beta}{(1-\beta\psi\tilde{y}_t)^2}-E_{t-1}\left[\left(\frac{\exp(\phi\tilde{y}_t)-1}{\phi}\right)\right]\theta\alpha$$

$$+A(i_t-i_{t-1})-\delta AE_{t-1}(i_{t+1}-i_t)=0. \tag{9}$$

Based on the above equation, several models can be specified by combining nonlinearity conditions. For example, when the condition $\varphi=\phi=\psi=0$ is imposed, the FOC (9) reduces to the following:

$$-\alpha\beta E_{t-1}(\pi_t-\pi^*)-\theta\alpha E_{t-1}\tilde{y}_t+A(i_t-i_{t-1})-\delta AE_{t-1}(i_{t+1}-i_t)=0. \tag{10}$$

Equation (10) can be derived directly from the quadratic objective function of the central bank with a linear system of the economy.

Now, we proceed to an empirical specification. Equation (9) cannot be estimated easily since the equation is not linear in the parameters. Therefore, by taking the first order Taylor series expansion at $\varphi=\phi=\psi=0$, the exponential terms and the inverse function in equation (9) can be approximated, and then equation (9) can be written as

$$-\alpha\beta E_{t-1}(\pi_t-\pi^*)-\theta\alpha E_{t-1}\tilde{y}_t-\frac{\varphi\alpha\beta}{2}E_{t-1}(\pi_t-\pi^*)^2-\frac{\phi\theta\alpha}{2}E_{t-1}\tilde{y}_t^2$$

$$-2\beta^2\psi\alpha E_{t-1}[(\pi_t-\pi^*)\tilde{y}_t]+A(i_t-i_{t-1})-\delta AE_{t-1}(i_{t+1}-i_t)+\varepsilon_t=0, \tag{11}$$

where ε_t represents the remaining terms of the Taylor series expansion.

Solving for Δi_t, the model for empirical analysis can be written as follows:

$$\Delta i_t=\delta\,\Delta i_{t+1}+c_1\tilde{\pi}_t+c_2\tilde{y}_t+c_3\tilde{\pi}_t^2+c_4\tilde{y}_t^2+c_5(\tilde{\pi}_t\tilde{y}_t)+u_t, \tag{12}$$

where $\tilde{\pi}_t=\pi_t-\pi^*$ and $E_{t-1}(u_t)=0$.

Equation (12) can be solved recursively as follows:

$$\Delta i_t=\sum_{i=0}^{\infty}\delta^i[c_1\tilde{\pi}_{t+i}+c_2\tilde{y}_{t+i}+c_3\tilde{\pi}_{t+i}^2+c_4\tilde{y}_{t+i}^2+c_5(\tilde{\pi}_{t+i}\tilde{y}_{t+i})+u_{t+i}].$$

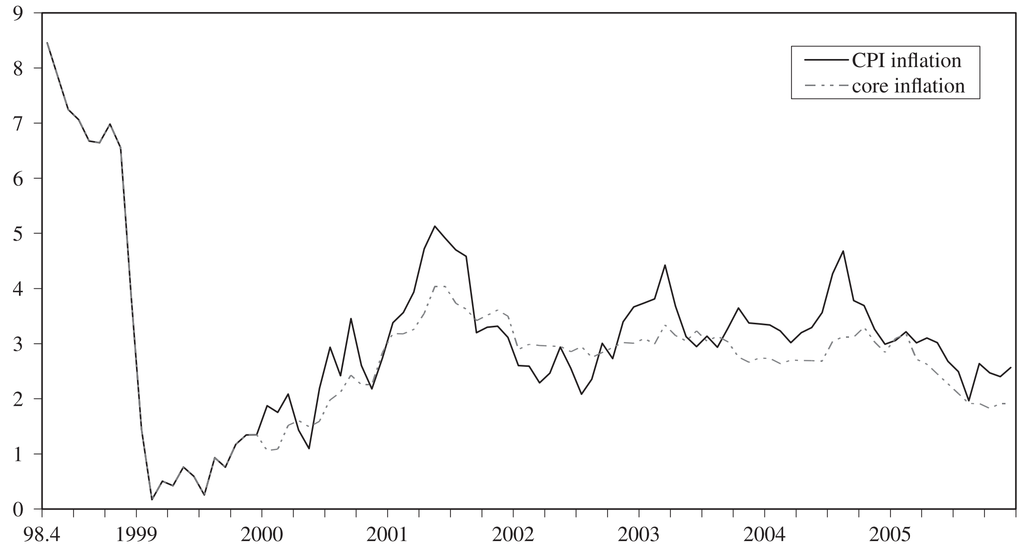
The change in the nominal interest rate depends on the discount value of future inflation and output gaps, their quadratic terms, and forecasting errors. The model (12) is linear in the coefficients, accompanying the inflation gap $\tilde{\pi}_t$, the output gap $\tilde{y}_t$, and their quadratic terms. The coefficients of (12) satisfy the following:

$$c_1\equiv\frac{\alpha\beta}{A},\ c_2\equiv\frac{\theta\alpha}{A},\ c_3\equiv\frac{\varphi\alpha\beta}{2A},\ c_4\equiv\frac{\phi\theta\alpha}{2A},\ c_5\equiv\frac{2\beta^2\psi\alpha}{A},\ \text{and}$$

$$u_t\equiv-\frac{1}{A}\left\{\begin{array}{c}(\delta/A)(\Delta i_{t+1}-E_{t-1}\Delta i_{t+1})+c_1(\tilde{\pi}_t-E_{t-1}\tilde{\pi}_t)+c_t(\tilde{y}_t-E_{t-1}\tilde{y}_t)\\+c_3(\tilde{\pi}_t^2-E_{t-1}\tilde{\pi}_t^2)+c_4(\tilde{y}_t^2-E_{t-1}\tilde{y}_t^2)+c_5\{\tilde{\pi}_t\tilde{y}_t-E_{t-1}(\tilde{\pi}_t\tilde{y}_t)\}+\varepsilon_t)\end{array}\right\}.$$

The error term is a linear combination of forecast errors and thus orthogonal to any variable in the information set available at t-1. Therefore, based on the orthogonality condition, the parameters in equation (12) can be estimated by the generalized method of moments (GMM). From the coefficients of the empirical model, we can recover the parameters of

Fig 1. Inflation Rates



asymmetric preferences over inflation gap and output gap such as $\varphi=2c_3/c_1$ and $\phi=2c_4/c_2$. However, the parameters of the weight on output gap relative to inflation (θ) and the degree of nonlinearity in AS curve (ψ) cannot be recovered without knowing the parameter β in the AS curve. The focus of this paper is to estimate the asymmetric preference parameters and assess whether those parameters are statistically significant. Therefore, we do not try to recover ψ while we maintain the cross-product term as a control variable for nonlinear AS relation. In empirical analysis, we estimate the preference parameters in various specifications using the combination of nonlinearity conditions. For example, we can estimate equation (12) assuming either a linear or nonlinear AS curve.

III. *Data*

In the empirical analysis, we use the monthly data for overnight call rate, yield on the 5-year government bond, consumer price index (CPI), core consumer price index (core CPI) and industrial production index (IPI), which are obtained from the Bank of Korea's Economic Statistics System.[3] The 12-month inflation rate is calculated based on CPI or core CPI, which excludes certain non-grain agricultural products and petroleum products from CPI. That is, $\pi_t=(\log P_t-\log P_{t-12})\times 100$ where P_t is CPI or core CPI. We call the inflation based on CPI as the CPI inflation, and the inflation based on core CPI as the core inflation. As Figure 1 shows, these two inflation series move closely together although the core inflation is more stable than the CPI inflation.

After the operating system of inflation targeting began, the target inflation was constructed

[3] http://ecos.bok.or.kr/

FIG 2. INFLATION GAPS

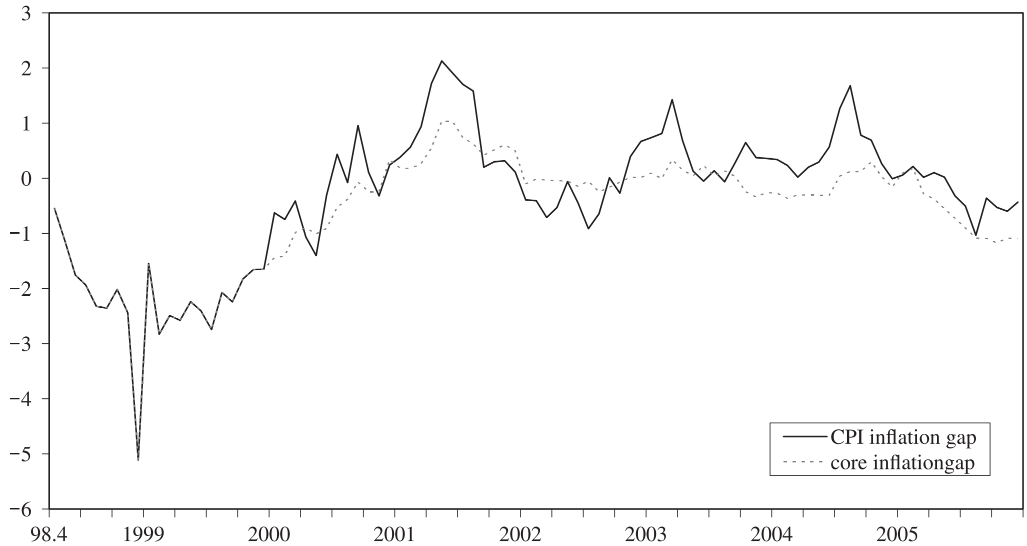
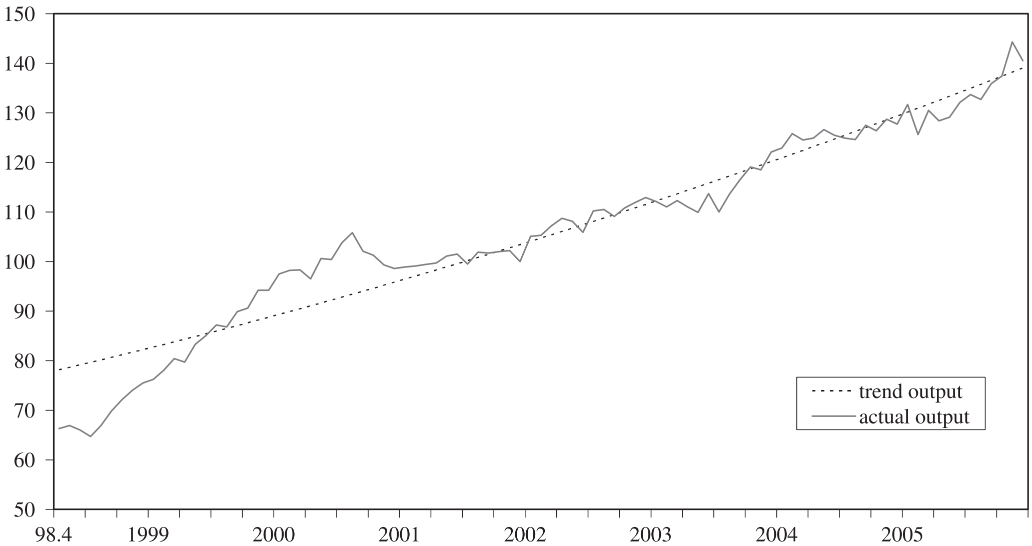


FIG 3. INDUSTRIAL PRODUCTION



in terms of CPI until 1999: 12. However, since 2000, the method of computing the target inflation has been changed in terms of the core CPI. Because the core CPI inflation does not include certain non-grain agricultural products and petroleum products, we consider the CPI inflation as well in our analysis. Figure 2 shows the inflation gap defined as the difference between the (core) CPI inflation and the target. The target inflation is obtained from the

FIG 4. ESTIMATED OUTPUT GAP

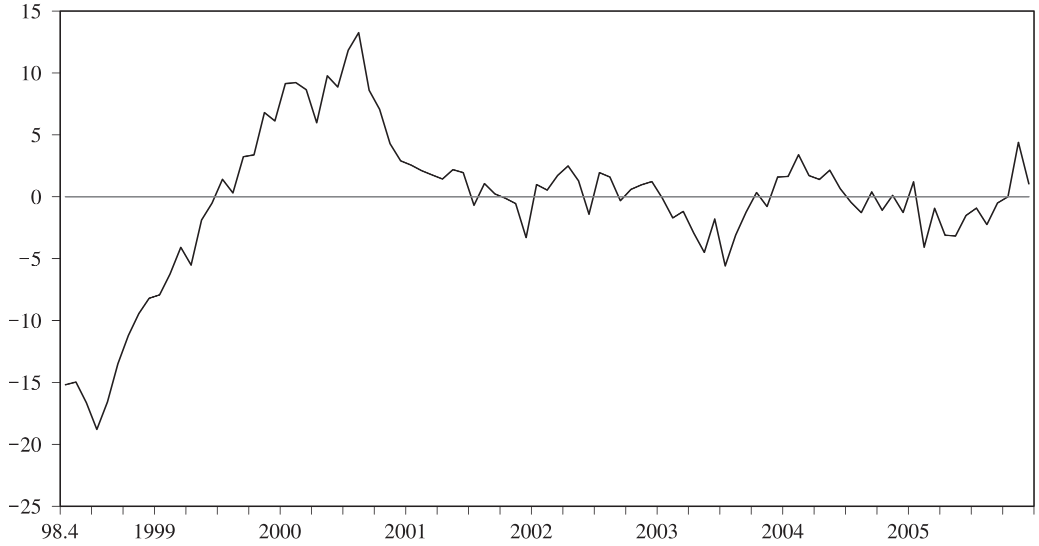


TABLE 1. DESCRIPTIVE STATISTICS

	Call rate	Output gap	Inflation		
			CPI	Core	Target
Mean	4.430	0.558	2.926	2.641	3.205
Standard deviation	0.980	4.618	1.305	1.194	1.283

Note: 1) Sample period is from 1998:9 to 2005:12.
2) CPI inflation is annual inflation rate calculated on Consumer Price Index, while core inflation is calculated based on CPI until 1999:12 but after that based on Core CPI. Output gap is estimated using a quadratic trend.

TABLE 2. THE CHANGE OF THE TARGET INTEREST RATES

Date of change		The target rate (%)	The change (%)
1999	May 6	4.75	-
2000	February 10	5.00	+0.25
	October 5	5.25	+0.25
2001	February 8	5.00	-0.25
	July 5	4.75	-0.25
	August 9	4.50	-0.25
	September 19	4.00	-0.50
2002	May 7	4.25	+0.25
2003	May 13	4.00	-0.25
	July 10	3.75	-0.25
2004	August 12	3.50	-0.25
	November 11	3.25	-0.25
2005	October 11	3.50	+0.25
	December 8	3.75	+0.25

Sources: The Bank of Korea

FIG 5. INTEREST RATES

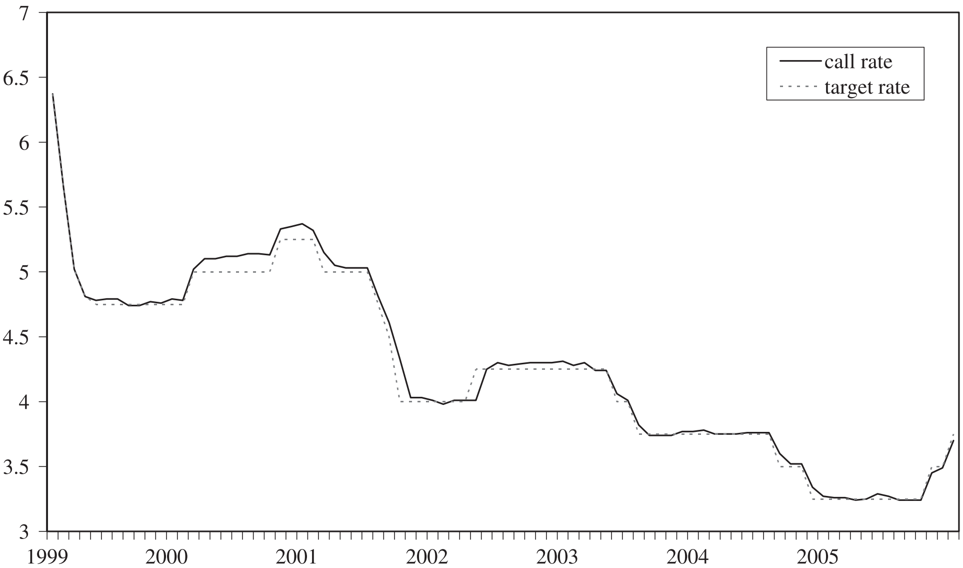


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Figure 3 shows the industrial production and its trend. Output gap series are constructed from the seasonally adjusted IPI using a quadratic de-trending method over 1998: 1-2005: 12. Specifically, output gap is measured as the actual output's percentage deviation from the trend output: $\tilde{y}_t = \{(q_t - q_t^*)/q_t^*\} \times 100$ where q_t is the actual output and q_t^* is the trend output. The estimated output gap series are shown in Figure 4.

The empirical analysis is performed for the sample period of inflation targeting 1998: 4-2005: 12. Since the initial five observations are used for central bank's information set, the actual sample used for estimating the reaction function is 1998: 9-2005: 12. The descriptive statistics of the variables considered here are summarized in Table 1. The target interest rate and its change are summarized in Table 2. The overnight call rate and the target interest rate are shown in Figure 5.

IV. *Empirical Results*

Table 3 shows the estimation results of the monetary policy reaction function, equation (12). The constant term is included in the empirical analysis with the intercept coefficient c_0. The parameter estimates are obtained by GMM with instrumental variables of the constant, inflation rate, output gap, the call rate, and the term spread between the call rate and the yield on 5-year Treasury bonds, and their lagged variables up to the fifth lag order. Table 3 reports the results of estimating various specifications of the monetary policy reaction function that allow for asymmetric response to the inflation gap or/and the output gap with or without nonlinear AS curve. Since the target inflation is based on the core inflation in Korea, Table 3

TABLE 3. ESTIMATES OF THE REACTION FUCNTION

Model: $\Delta i_t = \delta\ \Delta i_{t+1} + c_0 + c_1 \tilde{\pi}_t + c_2 \tilde{y}_t + c_3 \tilde{\pi}_t^2 + c_4 \tilde{y}_t^2 + c_5(\tilde{\pi}_t \tilde{y}_t) + u_t$

Model	δ	c_0	c_1	c_2	c_3	c_4	c_5	J	$\bar{R}^2$
a. Linear reaction function									
	0.855**	0.006	0.023**	0.005*	-	-	-	0.138	0.498
	(0.026)	(0.005)	(0.005)	(0.002)					
b. Nonlinear reaction function with inflation gap only									
$\tilde{\pi}_t^2$	0.849**	0.010+	0.049**	0.006**	0.011	-	-	0.136	0.523
	(0.031)	(0.005)	(0.015)	(0.002)	(0.007)				
$\tilde{\pi}_t^2$, $\tilde{\pi}_t \tilde{y}_t$	0.835**	0.009+	0.042**	0.005	0.008	-	-0.001	0.136	0.512
	(0.047)	(0.005)	(0.016)	(0.003)	(0.008)		(0.003)		
c. Nonlinear reaction function with output gap only									
$\tilde{y}_t^2$	0.923**	0.005	0.024**	0.003+	-	0.0003	-	0.134	0.454
	(0.047)	(0.006)	(0.007)	(0.002)		(0.0003)			
$\tilde{y}_t^2$, $\tilde{\pi}_t \tilde{y}_t$	0.864**	0.003	0.024**	-0.006	-	0.0005	-0.007+	0.120	0.415
	(0.042)	(0.007)	(0.009)	(0.006)		(0.0004)	(0.004)		
d. Nonlinear reaction function with inflation gap and output gap									
$\tilde{\pi}_t^2$, $\tilde{y}_t^2$	0.923**	0.010+	0.050**	0.004+	0.012+	0.0003	-	0.133	0.482
	(0.059)	(0.006)	(0.015)	(0.002)	(0.007)	(0.0003)			
$\tilde{\pi}_t^2$, $\tilde{y}_t^2$, $\tilde{\pi}_t \tilde{y}_t$	0.882**	0.007	0.045**	-0.006	0.009	0.0006	-0.007	0.122	0.442
	(0.055)	(0.007)	(0.021)	(0.007)	(0.009)	(0.0004)	(0.005)		

Notes: 1) The estimation period is from 1998:9 to 2005:12.
2) Output gap is obtained from percentage change of actual and detrending industrial production index with quadratic trend equation for the sample period 1998:1-2005:12.
3) The instrument sets include constant and five lags of core inflation, output gap, long-short interest rate spread and call rate.
4) The superscript **, * and + denote the rejection of the null hypothesis that the true coefficient is zero at the 1 percent, 5 percent and 10 percent significance levels, respectively.

uses the core inflation. Over various specifications the estimates of the discount factor are all significant, ranging from 0.835 to 0.923. These values are relatively small compared to the subjective rate of time discount in utility function of a representative household generally used in the standard real-business-cycle literature[4]. Another interesting result is that when the cross-product term of inflation gap and output gap is added in the reaction function, the coefficients have negative values although the coefficients are insignificant at the 5% size. This fact does not conform to the steep AS curve, which incorporates the capacity constraint in the range of positive output gap. The data reveals that the response of the inflation gap to the increase in the output gap is relatively flat.

Table 3.a reports the estimation results of the baseline linear reaction function, which can be obtained by imposing the condition $c_3 = c_4 = c_5 = 0$ on equation (12). The coefficients on inflation and output gaps are significant at the 1% significance level. The results display how much the Bank of Korea reacted toward the inflation and output gaps. Table 3.b and Table 3.c show nonlinear reaction to the inflation gap and the output gap, respectively. Table 3.d shows

[4] Walsh (2003, p. 75) assumed the subjective rate of time discount in utility function at 0.989 for quarterly data. The value corresponds to 0.996 for monthly data.

TABLE 4. ESTIMATES OF THE ASYMMETRIC PREFERENCES

Model: $\Delta i_t = \delta\, \Delta i_{t+1} + c_0 + \varphi\{(2c_3\varphi)\tilde{\pi}_t + c_3\tilde{\pi}_t^2\} + \phi\{(2c_4/\phi)\tilde{y}_t + c_4\tilde{y}_t^2\} + c_5(\tilde{\pi}_t\tilde{y}_t) + u_t$

Model	Inflation gap (φ)	Output gap (ϕ)	J	$\bar{R}^2$
a. Inflation gap only				
$\tilde{\pi}_t^2$	0.464**	-	0.136	0.522
	(0.161)			
$\tilde{\pi}_t^2$, $\tilde{\pi}_t\tilde{y}_t$	0.385	-	0.136	0. 513
	(0.231)			
b. Output gap only				
$\tilde{y}_t^2$	-	0.176	0.134	0.453
		(0.210)		
$\tilde{y}_t^2$, $\tilde{\pi}_t\tilde{y}_t$	-	-0.174	0.120	0.415
		(0.112)		
c. Inflation gap and output gap				
$\tilde{\pi}_t^2$, $\tilde{y}_t^2$	0.483**	0.147	0.133	0.482
	(0.157)	(0.212)		
$\tilde{\pi}_t^2$, $\tilde{y}_t^2$, $\tilde{\pi}_t\tilde{y}_t$	0.411+	-0.198	0.122	0.442
	(0.238)	(0.145)		

Notes: 1) The estimation period is from 1998:9 to 2005:12.
2) Output gap is obtained from percentage change of actual and detrending industrial production index with quadratic trend equation for the sample period 1998:1-2005:12.
3) The instrument sets include constant and five lags of core inflation, output gap, long-short interest rate spread and call rate.
4) The superscript **, * and + denote the rejection of the null hypothesis that the true coefficient is zero at the 1 pecent, 5 percent and 10 percent significance levels, respectively.

nonlinear reaction to the inflation and output gaps jointly. Each panel includes the estimation result with nonlinear AS curve.

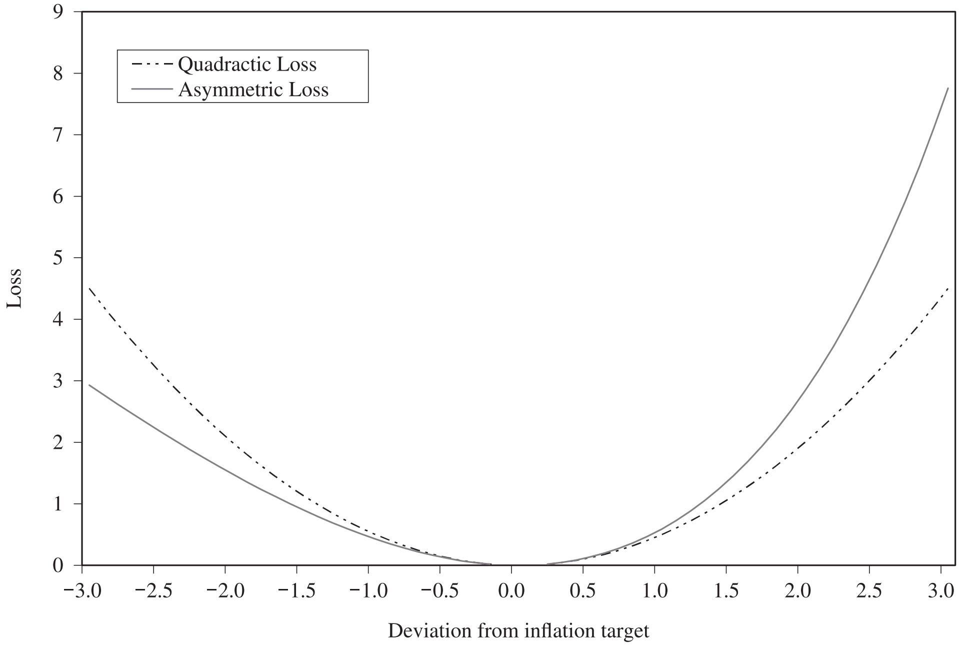
Table 4 shows the estimates of the asymmetric preference parameters. The parameters of asymmetric preferences can be recovered from estimated coefficients of the reaction function using the relationship as $\varphi = 2c_3/c_1$ and $\phi = 2c_4/c_2$. To obtain the standard errors of these estimates, we run an auxiliary regression as follows:

$$\Delta i_t = \delta \Delta i_{t+1} + c_0 + \varphi\{(2a/\varphi)\tilde{\pi}_t + a\tilde{\pi}_t^2\} + \phi\{(2b/\phi)\tilde{y}_t + \phi\tilde{y}_t^2\} + c_5(\tilde{\pi}_t\tilde{y}_t) + u_t\,. \quad (13)$$

The asymmetry parameter on the inflation gap is significant at the 1% significance level when we assume the linear AS curve. The estimates of asymmetry parameter on the inflation gap do not vary so much across various specifications of the reaction function. This result indicates that the Bank of Korea performed the monetary policy characterized by asymmetric preferences with regard to the inflation gap. The Bank of Korea put more weight on the positive-side deviations of inflation from the target than the negative-side deviations.

Figure 6 shows asymmetric preferences to the inflation gap. The dotted line depicts the standard quadratic loss function. The asymmetry parameter used in Figure 6 is $\varphi = 0.483$, which is from Table 4.c. A positive-side deviation of inflation increases the loss function sharply, and the central bank is likely to increase the interest rate to reduce the inflation gap. However, a negative-side deviation of inflation is less burdening compared to a positive-side deviation, and

FIG 6. ASYMMETRIC PREFERENCES WITH RESPECT TO THE INFLATION GAP



the central bank tends to fare with negative inflation gap.

On the other hand, the asymmetry preference parameter on the output gap is not significant in all specifications considered. The asymmetry parameter values are relatively small, and the sign of parameter estimates depends on the nonlinearity of the AS curve. Therefore, the results do not support the views that the Bank of Korea cared more about the negative-side output gap than the positive-side deviations.

The empirical results indicate that the asymmetric preference of the central bank leads to nonlinear reaction to the inflation gap. The central bank reacts more strongly to the positive inflation gap than to the negative inflation gap. This result is different from the dynamic inconsistency, which was analyzed by Kydland and Prescott (1977) and Rogoff (1985). The time inconsistency implies that the central bank is likely to allow for the positive inflation gap. However, as the central bank maintains the monetary policy rules with a strong commitment to inflation targeting, the dynamic inconsistency and the inflation bias are not likely to be severe.

Next, we consider sensitivity analysis to see whether our results hold with different parameter values of time discount. The estimated discount factor in equation (12) is relatively small compared to the value normally assumed for the calibration model of the representative household. We examine the robustness of estimation results by imposing some specific value of the discount factor in equation (12). Table 5 shows the estimation results for $\delta = 0.996$. It is not surprising that the model fitness diminishes. One interesting result is that the squares of output gap become significant statistically although the estimated coefficients become small. The squares of inflation gap in the reaction function are significant statistically.

Table 6 reports the estimation results of asymmetry parameters if the parameter value is

TABLE 5. ESTIMATES OF THE REACTION FUNCTION (δ =0.996)

Model: $\Delta i_t = \delta \Delta i_{t+1} + c_0 + c_1 \tilde{\pi}_t + c_2 \tilde{y}_t + c_3 \tilde{\pi}_t^2 + c_4 \tilde{y}_t^2 + c_5(\tilde{\pi}_t \tilde{y}_t) + u_t$

Model	δ	c_0	c_1	c_2	c_3	c_4	c_5	J	$\bar{R}^2$
a. Linear reaction function									
	0.996	0.012+	0.022**	0.003+	-	-	-	0.150	0.454
		(0.006)	(0.006)	(0.002)					
b. Nonlinear reaction function with inflation gap only									
$\tilde{\pi}_t^2$	0.996	0.022**	0.091**	0.005**	0.030**	-	-	0.154	0.504
		(0.007)	(0.010)	(0.002)	(0.004)				
$\tilde{\pi}_t^2$, $\tilde{\pi}_t \tilde{y}_t$	0.996	0.012*	0.041**	0.010**	0.012*	-	0.006**	0.141	0.458
		(0.006)	(0.011)	(0.003)	(0.005)		(0.002)		
c. Nonlinear reaction function with output gap only									
$\tilde{y}_t^2$	0.996	0.004	0.020**	0.001	-	0.0005**	-	0.132	0.421
		(0.006)	(0.007)	(0.001)		(0.0002)			
$\tilde{y}_t^2$, $\tilde{\pi}_t \tilde{y}_t$	0.996	-0.002	0.021*	-0.007	-	0.0009*	-0.006	0.121	0.365
		(0.007)	(0.008)	(0.007)		(0.0004)	(0.005)		
d. Nonlinear reaction function with inflation gap and output gap									
$\tilde{\pi}_t^2$, $\tilde{y}_t^2$	0.996	0.010+	0.053**	0.002	0.014*	0.0005**	-	0.131	0.452
		(0.006)	(0.014)	(0.001)	(0.006)	(0.0002)			
$\tilde{\pi}_t^2$, $\tilde{y}_t^2$, $\tilde{\pi}_t \tilde{y}_t$	0.996	0.010	0.063**	-0.008	0.018+	0.0009*	-0.006	0.122	0.420
		(0.007)	(0.020)	(0.008)	(0.009)	(0.0004)	(0.005)		

Notes: 1) The estimation period is from 1998:9 to 2005:12.
2) Output gap is obtained from percentage change of actual and detrending industrial production index with quadratic trend equation for the sample period 1998:1-2005:12.
3) The instrument sets include constant and five lags of core inflation, output gap, long-short interest rate spread and call rate.
4) The superscript **, * and + denote the rejection of the null hypothesis that the true coefficient is zero at the 1 percent, 5 percent and 10 percent significance levels, respectively.

set at δ =0.996. The estimated asymmetric preference parameter on the inflation gap is statically significant regardless of the functional form of the AS curve as shown in Table 6.a. As reported in Table 6.b the estimated preference parameter on the output gap is not significant statistically. In the model with asymmetric preferences on the inflation and output gaps, the asymmetry parameter of the inflation gap is significant and positive regardless of the functional form of the AS curve. The asymmetry parameter on the output gap is not significant, which is consistent with the previous results with the estimated discount factor.

Although the Bank of Korea changed its target inflation as core inflation from CPI inflation since 2000, they might still care about the CPI inflation. Here, our analysis is extended to the CPI inflation targeting. As the CPI inflation reflects the price changes of non-grain agricultural products and energy, its variation increases compared to that of the core CPI inflation. Table 7 reports the estimation results of the reaction function for CPI inflation. The square terms of inflation gap and output gap are significant while the sign of coefficients on the squares of output gap becomes negative in 3 of 4 specifications. When we use the CPI inflation, the coefficients on the squared of output gap are statistically significant while they are negative in sign. This result indicates that the central bank may dislike the output deviations from the potential output more as the output gap increases. The cross terms of inflation gap and

TABLE 6. ESTIMATES OF THE ASYMMETRIC PREFERENCES (δ = 0.996)

Model: $\Delta i_t = \delta\ \Delta i_{t+1} + c_0 + \varphi\{(2c_3\varphi)\tilde{\pi}_t + c_3\tilde{\pi}_t^2\} + \phi\{(2c_4/\phi)\tilde{y}_t + c_4\tilde{y}_t^2\} + c_5(\tilde{\pi}_t\tilde{y}_t) + u_t$

Model	Inflation gap (φ)	Output gap (ϕ)	J	$\bar{R}^2$
a. Inflation gap only				
$\tilde{\pi}_t^2$	0.667**	-	0.154	0.504
	(0.040)			
$\tilde{\pi}_t^2,\ \tilde{\pi}_t\tilde{y}_t$	0.579**	-	0.141	0. 458
	(0.125)			
b. Output gap only				
$\tilde{y}_t^2$	-	1.035	0.132	0.421
		(1.295)		
$\tilde{y}_t^2,\ \tilde{\pi}_t\tilde{y}_t$	-	-0.238	0.121	0.365
		(0.157)		
c. Inflation gap and output gap				
$\tilde{\pi}_t^2,\ \tilde{y}_t^2$	0.538**	0.672	0.131	0.452
	(0.134)	(0.517)		
$\tilde{\pi}_t^2,\ \tilde{y}_t^2,\ \tilde{\pi}_t\tilde{y}_t$	0.565**	-0.242	0.122	0.420
	(0.142)	(0.170)		

Notes: 1) The estimation period is from 1998:9 to 2005:12.
2) Output gap is obtained from percentage change of actual and detrending industrial production index with quadratic trend equation for the sample period 1998:1-2005:12.
3) The instrument sets include constant and five lags of core inflation, output gap, long-short interest rate spread and call rate.
4) The superscript **, * and + denote the rejection of the null hypothesis that the true coefficient is zero at the 1 pecent, 5 percent and 10 percent significance levels, respectively.

output gap are not significant in all specifications.

The estimates of the asymmetry parameters are shown in Table 8. The asymmetry parameters on the inflation gap are significant in 2 of 4 specifications and those values are bigger than those provided in Table 4. Asymmetry parameters on output gap become significant in 2 of 4 specifications.

V. *Concluding Remarks*

The Bank of Korea has adopted the explicit inflation targeting since 1998. Therefore, the change in the operating procedure provides an interesting environment for testing whether the preferences of the Bank of Korea are consistent with the quadratic preference assumption that is conceived standard within the monetary policy literature. Using linear-exponential function instead of the standard quadratic function, this paper examines the asymmetric preferences of the Bank of Korea with regard to inflation gap and output gap under the new Keynesian economic framework. The nonlinear monetary policy reaction function is derived from the optimization behavior of the central bank. In addition, we introduce the possibility that AS curve is not linear, which also induces the nonlinear monetary reaction function.

We estimate the reaction function and the asymmetric preference parameters on the

TABLE 7. ESTIMATES OF THE REACTION FUNCTION (CPI inflation)

Model: $\Delta i_t = \delta \Delta i_{t+1} + c_0 + c_1 \tilde{\pi}_t + c_2 \tilde{y}_t + c_3 \tilde{\pi}_t^2 + c_4 \tilde{y}_t^2 + c_5 (\tilde{\pi}_t \tilde{y}_t) + u_t$

Model	δ	c_0	c_1	c_2	c_3	c_4	c_5	J	$\bar{R}^2$
a. Linear reaction function									
	0.863**	-0.001	0.016**	0.005**	-	-	-	0.148	0.497
	(0.027)	(0.005)	(0.005)	(0.002)					
b. Nonlinear reaction function with inflation gap only									
$\tilde{\pi}_t^2$	0.887**	-0.014*	0.052**	0.007**	0.025**	-	-	0.149	0.480
	(0.037)	(0.006)	(0.009)	(0.002)	(0.003)				
$\tilde{\pi}_t^2$, $\tilde{\pi}_t \tilde{y}_t$	0.847**	-0.019*	0.059**	0.006*	0.030**	-	-0.002	0.150	0.484
	(0.049)	(0.008)	(0.012)	(0.003)	(0.005)		(0.002)		
c. Nonlinear reaction function with output gap only									
$\tilde{y}_t^2$	0.517**	-0.002	0.011+	0.016**	-	-0.0014**	-	0.137	0.614
	(0.071)	(0.005)	(0.007)	(0.002)		(0.0003)			
$\tilde{y}_t^2$, $\tilde{\pi}_t \tilde{y}_t$	0.871**	-0.006	0.013+	0.0003	-	0.0002	-0.003	0.146	0.470
	(0.041)	(0.006)	(0.007)	(0.0004)		(0.0004)	(0.003)		
d. Nonlinear reaction function with inflation gap and output gap									
$\tilde{\pi}_t^2$, $\tilde{y}_t^2$	0.726**	-0.015*	0.054**	0.012**	0.026**	-0.0006*	-	0.154	0.524
	(0.075)	(0.007)	(0.011)	(0.003)	(0.003)	(0.0003)			
$\tilde{\pi}_t^2$, $\tilde{y}_t^2$, $\tilde{\pi}_t \tilde{y}_t$	0.532**	0.005	0.009*	-0.009	-0.009	-0.0009+	-0.004	0.119	0.532
	(0.076)	(0.008)	(0.005)	(0.005)	(0.005)	(0.0005)	(0.003)		

Notes: 1) The estimation period is from 1998:9 to 2005:12.
2) Output gap is obtained from percentage change of actual and detrending industrial production index with quadratic trend equation for the sample period 1998:1-2005:12.
3) The instrument sets include constant and five lags of CPI inflation, output gap, long-short interest rate spread and call rate.
4) The superscript **, * and + denote the rejection of the null hypothesis that the true coefficient is zero at the 1 percent, 5 percent and 10 percent significance levels, respectively.

inflation gap and the output gap for the sample period of inflation targeting 1998:9-2005:12. The empirical results show that the asymmetry parameter of the inflation gap is statistically significant. Thus, our result indicates that the BOK has placed more weight on positive deviations of inflation from the target than on negative deviations.

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TABLE 8. ESTIMATES OF THE ASYMMETRIC PREFERENCES (CPI Inflation)

Model: $\Delta i_t = \delta \, \Delta i_{t+1} + c_0 + \varphi\{(2c_3\varphi)\tilde{\pi}_t + c_3\tilde{\pi}_t^2\} + \phi\,\{(2c_4/\phi)\tilde{y}_t + c_4\tilde{y}_t^2\} + c_5(\tilde{\pi}_t\tilde{y}_t) + u_t$

Model	Inflation gap (φ)	Output gap (ϕ)	J	$\bar{R}^2$
a. Inflation gap only				
$\tilde{\pi}_t^2$	0.976**	-	0.149	0.480
	(0.101)			
$\tilde{\pi}_t^2,\ \tilde{\pi}_t\tilde{y}_t$	1.002**	-	0.150	0. 484
	(0.104)			
b. Output gap only				
$\tilde{y}_t^2$	-	-0.171**	0.137	0.614
		(0.025)		
$\tilde{y}_t^2,\ \tilde{\pi}_t\tilde{y}_t$	-	-0.212	0.143	0.460
		(0.226)		
c. Inflation gap and output gap				
$\tilde{\pi}_t^2,\ \tilde{y}_t^2$	4.679	-0.199	0.119	0.572
	(7.193)	(0.022)		
$\tilde{\pi}_t^2,\ \tilde{y}_t^2,\ \tilde{\pi}_t\tilde{y}_t$	-2.455	-0.221**	0.140	0.380
	(4.534)	(0.039)		

Notes: 1) The estimation period is from 1998:9 to 2005:12.
2) Output gap is obtained from percentage change of actual and detrending industrial production index with quadratic trend equation for the sample period 1998:1-2005:12.
3) The instrument sets include constant and five lags of CPI inflation, output gap, long-short interest rate spread and call rate.
4) The superscript **, * and + denote the rejection of the null hypothesis that the true coefficient is zero at the 1 pecent, 5 percent and 10 percent significance levels, respectively.

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