Endogeneity of the Inflation Target†

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Abstract

Under inflation targeting, central banks set an inflation target in advance and then try to make an actual inflation reach the target. However, central banks may have an incentive to adjust the target endogenously to previous or expected inflation rates to close the gap between the actual inflation rate and the target. This study examines the issue of inflation target endogeneity by using various empirical methods with a sample of 19 inflation-targeting countries. Empirical results show that an increase in actual or expected inflation rate has a significantly positive effect on the inflation target of the next period. The result further suggests that endogeneity of the inflation target is more evident in central banks with low credibility or weak performance than in those with high credibility or strong performance. Finally, we construct a simple theoretical model to illustrate that the endogeneity of the inflation target can lead to equilibrium indeterminacy and an increase in the volatility of the inflation rate.

Keywords: Inflation Targeting, Inflation Rate, Inflation Target, Endogeneity
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1. Introduction

Since New Zealand adopted inflation targeting in 1990, an increasing number of countries have adopted it as well. As a result, actual inflation rates in many countries, even emerging ones, have decreased sharply after the inflation targeting system was introduced. In fact, more than 30 countries have currently adopted the system.

However, some previous studies have challenged the success of inflation targeting by arguing that its adoption is an endogenous choice. In a debate on the macroeconomic performance evaluation of the inflation targeting system, Ball and Sheridan (2005) indicated that the inflation levels of inflation-targeting adopters were relatively higher than those of non-adopters during the pre-inflation targeting period. On the basis of this observation, Ball and Sheridan (2005) claimed that the stabilizing effects from the adoption of inflation targeting, which were argued by Bernanke et al. (1999), were likely to be a "regression to the mean" phenomenon. In other words, although inflation level and real GDP volatility decreased in countries that adopted inflation targeting, the phenomenon was a mere reaction to the high inflation rate and real GDP volatility of the pre-inflation targeting period. Ball and Sheridan (2005) showed that no evidence of a causal relation existed in the adoption of inflation targeting to improve economic performance because the adoption decision was made endogenously. Following the study of Ball and Sheridan (2005), many studies have investigated this endogeneity issue when measuring the performance of inflation targeting (e.g., Uhlig (2004), Mishkin and Schmidt-Hebbel (2002), Gertler (2005), Mishkin (2005)).[2]

The present study emphasizes another type of endogeneity issue in inflation targeting. Rather than discussing the endogeneity of the adoption of inflation targeting as in previous studies, the current study analyzes the endogeneity of an inflation target itself under inflation targeting. In other words, a central bank that has adopted inflation targeting may

[2] To resolve this endogeneity issue, a variety of methodologies have been proposed, such as difference in difference method (Cecchetti and Ehrmann (2000), Hu (2003), Neumann and von Hagen (2002)), controlling for initial conditions (Ball and Sheridan (2005), Gonçalvez and Salles (2008)), instrumental variable approach (Mishkin and Schmidt-Hebbel (2007)), and propensity score matching (Lin and Ye (2007, 2009), Vega and Winkelried (2005)). Svensson (2011) provides a survey of literature.

adjust its inflation target endogenously to the state of the economy, particularly to past or expected inflation rates.[3]

For example, the Bank of Indonesia set the following three-year inflation target in 2004: 6 ± 1% (2005), 5.5 ± 1% (2006), and 5 ± 1% (2007). However, when inflation rate increased more than expected (10.5% in 2005), the Bank of Indonesia adjusted the target in 2005 to 8 ± 1% (2006), 6 ± 1% (2007), and 5 ± 1% (2008).

Similarly, the central bank of Colombia decreased the annual inflation target from 22% (1993) to 19% (1994), 18% (1995), and 17% (1996) when inflation rate decreased from 27% in 1992 to 22.5% in 1993, 22.8% in 1994, and 20.9% in 1995. However, the central bank increased the target for 1997 to 18% because the inflation rate did not substantially decrease in 1996 (20.8%). Inflation rate then decreased to 18.5% in 1997, and the central bank lowered the target for 1998 to 16%, accordingly. As inflation rate further decreased from 18.7% in 1998 to 10.9% in 1999, the bank lowered the target yet again from 15% (1999) to 10% (2000). The central bank of Colombia has adjusted the target rate even in recent years due to changes in inflation rates. In fact, as inflation rate sharply increased from 5.5% in 2007 to 7% in 2008, the central bank raised the target from 3.5~4.5% (2008) to 4.5~5.5% (2009). The inflation rate then dropped in 2009 (4.2%). Subsequently, the target for 2010 decreased to 3 ± 1%. The correlation between the inflation target and the past inflation rate in Colombia is actually close to one.

Such endogeneity may occur because of various reasons. For example, under inflation targeting, central banks often face immense pressure in keeping the actual inflation rate within a target range. Thus, when the actual inflation rate deviates from the target, central banks may decide to change the inflation target to close the gap. In other words, central banks ideally set an inflation target first and then the actual inflation rate adjusts to the target. However, they may instead adjust an inflation target to the actual inflation rate, especially when meeting the target is difficult. In the above examples, central banks may have adjusted the target for the next period on the basis of their current inflation rate. Forward-looking central banks may also adjust the target for the next period on the basis of the expected inflation rate for the next period.

[3] From the viewpoint of a monetarist, the inflation target does not need to be dependent on any economic fundamentals (Anderson et al. (2014)).

With such endogeneity, inflation targeting may seem successful even when it is not. More importantly, such endogeneity may weaken the stabilizing role of inflation targeting. Under inflation targeting, the central bank is supposed to help stabilize inflation by setting the target, trying to achieve the target, showing such efforts to economic agents, and leading economic agents in setting inflation expectations close to the target. However, if central banks change the target according to past inflation rates or expectations, then the inflation expectations of economic agents and the actual inflation rates may not be stabilized. The reason is that the inflation target may not work as anchor for the inflation expectations of economic agents.

In this paper, we first investigate whether an actual inflation rate affects a future inflation target or whether an inflation target is influenced by past actual inflation rates by examining 19 inflation-targeting countries. We perform the Granger causality test, conduct a correlation and a simple regression analysis for individual countries, and then run panel regressions as a formal analysis. We also investigate whether the inflation expectation affects the inflation target. The results suggest that previous or expected inflation rates significantly influence the inflation target of the next period. In other words, endogeneity exists when central banks set their inflation targets. These results robustly stand against various modifications of the empirical model, such as considering reverse causality and reducing the sample period. We also divide the sample countries into two groups based on the performance of their central bank in meeting the inflation target, namely the high and low performance groups. The result shows that countries in the low performance group actively adjust inflation targets to the previous inflation level more than the high performance group. This result may suggest that central banks with low performance have further incentive to adjust an inflation target to reduce the gap between the actual inflation rate and the target.

We also construct a simple theoretical model to illustrate the consequences of inflation target endogeneity. We show that a unique equilibrium does not exist and that equilibrium is undetermined when the inflation target fully depends on the past or expected inflation rate. An increase in past (or expected) inflation rate increases the inflation target by the same amount, which in turn affects the actual inflation rate by the same amount. Therefore, no mechanism exists for stabilizing the inflation rate. Furthermore, the monetary authority should strongly increase the interest rate in response to the deviation of the actual inflation rate from the target when the inflation target depends on the previous or expected inflation rate, in order to avoid equilibrium indeterminacy. We also show that volatility of the inflation rate increases when the inflation target depends on the past or expected inflation rate.[4]

The rest of this paper is organized as follows. Section 2 explains the empirical methodology and Section 3 presents the empirical results. In Section 4, we conduct various extended analyses. Section 5 provides simple theoretical models to illustrate the consequences of inflation target endogeneity. Finally, Section 6 concludes the study with a summary of results.

2. Data and Empirical Method

2.1. Data

We consider the inflation rate and target data of 19 inflation-targeting countries: Brazil, Canada, Chile, Colombia, Czech Republic, Ghana, Guatemala, Hungary, Indonesia, Israel, Korea, Mexico, New Zealand, Peru, the Philippines, Poland, Romania, Thailand, and Turkey.[5] Although the International Financial Statistics (IFS) of the International Monetary

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[4] In analyzing the US economy, Ireland (2007) used the New Keynesian model in which inflation target depends on technology and mark-up shocks because the Fed may increase (decrease) the target in response to inflation rise (fall) due to such supply shocks. Ireland (2007) argued that such behavior of the Fed may have resulted in the persistent rise and fall of the inflation rate during the post-war period, supporting the argument of some studies, such as those by Blinder (1982), Hetzel (1998), and Bomfim and Rudebusch (2000). Although these studies investigated the US case which involved no explicit inflation targeting, they are consistent with the idea of the current paper that inflation can be volatile under inflation target endogeneity. On the other hand, some studies, such as that by Cogley et al. (2010), assumed that the inflation target is time-varying but still exogenously driven.

[5] As of April 2015, 32 countries have explicitly adopted inflation targeting as monetary policy. Among these countries, we exclude seven that have not made an inflation target decision more than once and six that have adopted inflation targeting only recently, say after the 2008–2009 global financial crisis. These 13 excluded countries are Armenia, Australia, Iceland, Norway, South Africa, Sweden, and the United Kingdom, comprising the first seven, and Albania, Georgia, India, Japan, Moldova, and Serbia, comprising the final six. By excluding these 13 countries, we are left with 19 countries.

We include both explicit and implicit targeting periods because the explicit inflation targeting period is often short and because we wish to observe the entire phenomenon of inflation targeting. Chile, Colombia, Ghana, Indonesia, Mexico, Peru, and Turkey implicitly indicated their inflation target because they were not sure whether they possessed the macroeconomic preconditions required for the successful management of inflation targeting. In the case of Ghana, however, we consider only the explicit inflation targeting period

Fund (IMF) is the main source of our inflation rate data, we also collect data from the webpage of each central bank because certain data such as core CPI and inflation target data are difficult to obtain from IFS. Some omitted values are also collected from IMF country reports and from the study of Mishkin and Savastano (2002).

2.2. Empirical Methodology

We use various empirical methods to investigate the relation between past inflation rates and current inflation targets. First, we examine preliminary data properties by conducting the Granger causality test for each country. Second, we calculate for correlation and run a simple regression per country to acquire a rough idea about the relation between past inflation rates and current inflation targets. Finally, we conduct the panel regression analysis to formally infer the relation.

We examine whether actual inflation rates Granger-cause mid-point targets in each country. The inflation targeting period is considered but with some exceptions. For Korea, we consider the period from 2000 to 2006, when the Bank of Korea targeted core CPI.[6] For the Czech Republic, we consider the period after 2002, when the Czech National Bank changed the target index from net CPI to headline CPI. For Indonesia, we analyze the period after 2003 in which monthly inflation data are made available. We exclude Thailand because the Bank of Thailand first changed its mid-point inflation target in 2015. We use monthly data to secure enough degrees of freedom.

We would like to conduct simple analysis on the relationship between an actual inflation rate and inflation target in each country before conducting the main regression analysis. We compute the correlation between current inflation target mid-point and previous inflation rate. We also conduct a regression of current inflation target mid-point on previous inflation rate. We use annual instead of monthly data because decisions on

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because data on its implicit inflation targeting period are not available. An analysis on the sample of only explicit inflation targeting periods is conducted in Section 4 to check the robustness of our main results. Details on the timing of each country's adoption of inflation targeting and changes in the inflation target are also summarized in Table A1 in the Appendix.

[6] This period was chosen because the period before 2000 is overly short, and the Bank of Korea changed the inflation target only once after 2006.

inflation target are made on the basis of annual frequency and because we wish to infer the behavior of central banks in setting inflation targets.

We use the mid-point of inflation targets in certain periods and the inflation performance of immediately preceding years. We also consider three ways of calculating past inflation performance: inflation rate of the previous year, average inflation of the past two years, and average inflation rate of previous inflation target years. For example, if the inflation target period is set to three years from 2013 to 2015, then the average of the mid-point of inflation target in 2013–2015 is compared with the inflation rate in 2012, the average inflation rate in 2011–2012, and the average inflation rate in 2010–2012. However, the length of the period at which this study measures inflation performance does not exceed three years.

We then conduct the panel regression analysis and consider two kinds of models. First, we run a simple regression model in which the mid-point of the inflation target is a dependent variable and past inflation rate is an explanatory variable.

$$\pi_{it}^{*} = \alpha_0 + \alpha_1 \pi_{it}^{P} + \varepsilon_{it}, \tag{1}$$

where π_{it}^{*} is the mid-point value of the inflation target, π_{it}^{P} is the inflation rate in the previous period, and ε_{it} is an error term. The exact definition of the variables is the same as that used in the correlation and regression analyses for individual countries.

Second, we extend the first model by adding the previous inflation target value as an explanatory variable because central banks may consider the previous inflation target value in setting the current one.

$$\pi_{it}^{*} = \beta_0 + \beta_1 \pi_{it}^{P} + \beta_2 \pi_{it-1}^{*} + \varepsilon_{it}, \tag{2}$$

where π_{it-1}^{*} is the previous inflation target value. In Equation (1), the previous inflation rate may have explanatory power even when the previous target explains the current target if the previous target and inflation rates are correlated. This possibility is controlled for in Equation (2).

3. Empirical Results

3.1. Granger Causality Test

Table 1 shows the results of the Granger causality test. Two results are reported for each country depending on whether the lag length is selected on the basis of the Akaike or the Schwartz Criterion.[7] The null hypothesis is that inflation rates do not Granger-cause inflation targets. In many countries, previous inflation rates help explain the movement of inflation targets. In 14 and 12 out of total 18 countries, the null hypothesis is rejected in at least one case at the 10% and 5% significance level, respectively. In eight countries (i.e., Chile, Colombia, Guatemala, Indonesia, Israel, the Philippines, Poland, and Turkey), the null hypothesis is rejected in both cases at the 5% significance level. These results suggest that previous inflation rates are likely to influence inflation targets in many countries.

3.2. Correlation and Regression for Individual Countries

Table 2 reports the correlation and β coefficients from the regression. In most countries, positive correlations are observed between inflation targets and past inflation performances. The correlations are negative in only three countries (i.e., Thailand, the Philippines, and New Zealand). In particular, the correlations are close to one in Israel, Poland, Chile, Colombia, Peru, Romania, and Turkey. In most countries, the correlation sign remains unchanged, and the magnitude of the correlation is similar regardless of how we measure past inflation performance. In fact, the Philippines and Thailand are the only countries whose correlation signs change when we evaluate past inflation performances in different ways.

Table 2 also reports the estimated β coefficients with their corresponding significance levels. As in the correlation analysis, the estimated β coefficients are all positive except for the same three countries. In addition, the estimated positive coefficients are significant at the 1%, 5%, and 10% level in 9, 10, and 12 countries, respectively, in at least one case and are larger than 0.5 in six countries.

[7] No lag is selected using either criterion for Korea. We use 1 lag.

Table 1: Granger Causality Test Results

	Akaike Criterion			Schwartz Criterion		
	Lag	F-value		lag	F-value	
Brazil	7	3.485^{***}	[0.002]	2	0.596	[0.552]
Canada	12	1.753^{*}	[0.056]	1	2.468	[0.117]
Chile	6	2.817^{**}	[0.011]	1	6.882^{***}	[0.009]
Colombia	6	8.386^{***}	[0.000]	2	11.606^{***}	[0.000]
Czech	3	1.601	[0.191]	1	1.237	[0.268]
Ghana	1	2.928^{*}	[0.090]	1	2.928^{*}	[0.090]
Guatemala	5	5.124^{***}	[0.000]	2	6.463^{***}	[0.002]
Hungary	2	0.560	[0.572]	1	1.013	[0.316]
Indonesia	4	11.263^{***}	[0.000]	1	7.934^{***}	[0.006]
Israel	7	4.289^{***}	[0.000]	2	3.471^{**}	[0.032]
Korea	1	2.780^{*}	[0.010]	1	2.780^{*}	[0.010]
Mexico	12	11.276^{***}	[0.000]	5	2.879^{**}	[0.015]
New Zealand	4	0.125	[0.973]	1	0.048	[0.827]
Peru	2	2.075	[0.128]	2	2.075	[0.128]
Philippines	2	4.334^{**}	[0.015]	2	4.334^{**}	[0.015]
Poland	2	3.545^{**}	[0.031]	2	3.545^{**}	[0.031]
Romania	12	2.186^{**}	[0.019]	1	0.240	[0.625]
Turkey	12	2.630^{***}	[0.004]	1	14.940^{***}	[0.000]

Notes: 1. The null hypothesis is that an actual inflation does not Granger-cause an inflation target.
2. The numbers in brackets are p-values, and the symbols *, **, and *** indicate that the estimates are significant at the 10%, 5%, and 1% level, respectively.

Table 2: Relation between the Inflation Target and Past Inflation Rates

Country	Inflation Target vs. Inflation rate in the previous year: Correlation coefficient	β coefficient	Average inflation rate in the past two years: Correlation Coefficient	β coefficient	Average inflation rate in the past target horizon (maximum of three years): Correlation coefficient	β coefficient
Brazil	0.142	0.024 [0.043]	0.060	0.013 [0.056]	0.148	0.025 [0.043]
Canada	0.905	0.436** [0.103]	0.971	0.446*** [0.055]	0.906	0.443** [0.103]
Chile	0.996	0.633*** [0.017]	0.969	0.644*** [0.052]	0.995	0.632*** [0.020]
Colombia	0.993	0.773*** [0.020]	0.995	0.772*** [0.018]	0.993	0.773*** [0.020]
Czech Republic	0.681	0.232* [0.111]	0.747	0.303* [0.120]	0.669	0.247 [0.123]
Ghana	0.468	0.283 [0.202]	0.238	0.179 [0.276]	0.468	0.283 [0.202]
Guatemala	0.579	0.150 [0.106]	0.629	0.285 [0.176]	0.832	0.357** [0.119]
Hungary	0.660	0.182 [0.093]	0.620	0.188 [0.107]	0.661	0.238 [0.121]
Indonesia	0.907	0.640*** [0.112]	0.528	0.493 [0.299]	0.814	0.646*** [0.174]
Israel	0.949	0.712*** [0.075]	0.965	0.724*** [0.062]	0.975	0.701*** [0.050]
Korea	0.284	0.287 [0.342]	0.362	0.539 [0.491]	0.256	0.267 [0.356]
Mexico	0.129	0.132 [0.385]	0.026	0.032 [0.463]	0.111	0.116 [0.394]
New Zealand	-0.030	-0.007 [0.086]	-0.178	-0.049 [0.103]	-0.588	-0.096* [0.050]
Peru	0.918	0.311*** [0.048]	0.911	0.234*** [0.037]	0.913	0.312*** [0.049]
Philippines	-0.168	-0.068 [0.127]	0.081	0.046 [0.178]	-0.229	-0.093 [0.125]
Poland	0.997	0.514*** [0.021]	0.967	0.508*** [0.067]	0.983	0.562*** [0.052]
Romania	0.948	0.440** [0.085]	0.996	0.409*** [0.020]	0.993	0.420*** [0.030]
Thailand	0.216	0.089 [0.286]	-0.175	-0.046 [0.184]	-0.136	-0.037 [0.191]
Turkey	0.958	0.542*** [0.066]	0.922	0.497*** [0.085]	0.949	0.549*** [0.074]

Notes: 1. β coefficients correspond to the coefficient on previous inflation rate from the regression of current inflation rate target mid-point on previous inflation rate.

2. The numbers in brackets are standard errors, and the symbols *, **, and *** indicate that the estimates are significant at the 10%, 5%, and 1% significance level, respectively.

3.3. Panel Regression

Table 3 shows the panel regression estimates for Equation (1) by the pooled OLS (POLS), fixed effects (FE), and random effects (RE) models. The estimates for the coefficient of the past inflation rate are significantly different from zero and are positive, supporting the idea that inflation performance affects the inflation target of the next period. The size of the estimated coefficients ranges from 0.43 to 0.54, and the coefficients are significant at the 1% level in all cases.

Table 3: Equation (1) Estimation Results

	POLS			**FE**			**RE**		
	π^*			π^*			π^*		
$const$	1.874*** [0.365]	2.099*** [0.393]	1.768*** [0.376]	2.382*** [0.394]	2.544*** [0.419]	2.275*** [0.405]	1.874*** [0.365]	2.131*** [0.442]	1.793*** [0.389]
π^{P1}	**0.538***** [0.030]			**0.479***** [0.035]			**0.538***** [0.030]		
π^{P2}		**0.479***** [0.030]			**0.431***** [0.035]			**0.463***** [0.031]	
π^{P3}			**0.539***** [0.031]			**0.482***** [0.036]			**0.532***** [0.031]
Observations	180	180	180	180	180	180	180	180	180
R^2	0.642	0.584	0.633	0.536	0.482	0.529			

Notes: 1. The numbers in brackets are standard errors, and the symbols *, **, and *** indicate that the estimates are significant at the 10%, 5%, and 1% level, respectively.
2. π^{P1} is the inflation rate of the previous year, π^{P2} is the average inflation rate of the past two years, and π^{P3} is the average inflation rate of the previous target horizon.

Table 4 shows the results of the estimation of Equation (2) which also include the inflation target of the previous period as independent variable. In all cases, the estimates for the coefficient of the previous inflation rate are significantly different from zero and are positive at the 1% significance level. However, the size of the estimates shrinks to 0.17–0.30. These results imply that past inflation performance affects inflation targets even after controlling for past inflation targets.

Table 4: Equation (2) Estimation Results

	POLS			FE			RE		
	π^*			π^*			π^*		
$const$	1.177*** [0.200]	1.131*** [0.209]	1.125*** [0.204]	1.360*** [0.208]	1.269*** [0.218]	1.282*** [0.211]	1.175*** [0.238]	1.103*** [0.238]	1.103*** [0.240]
π^*_{-1}	0.375*** [0.055]	0.477*** [0.050]	0.392*** [0.057]	0.318*** [0.053]	0.411*** [0.047]	0.315*** [0.055]	0.338*** [0.052]	0.440*** [0.047]	0.343*** [0.054]
π^{P1}	**0.271*** ** [0.046]			**0.297*** ** [0.043]			**0.287*** ** [0.043]		
π^{P2}		**0.174*** ** [0.038]			**0.212*** ** [0.036]			**0.193*** ** [0.036]	
π^{P3}			**0.258*** ** [0.048]			**0.304*** ** [0.045]			**0.285*** ** [0.045]
Observations	180	180	180	180	180	180	180	180	180
R^2	0.862	0.851	0.858	0.836	0.824	0.834			

Notes: 1. The numbers in brackets are standard errors, and the symbols *, **, and *** indicate that the estimates are significant at the 10%, 5%, and 1% level, respectively.
2. π^{P1} is the inflation rate of the previous year, π^{P2} is the average inflation rate of the past two years, and π^{P3} is the average inflation rate of the past target horizon.

As shown in Tables 3 and 4, the significant and positive relationship between current inflation targets and past inflation performances are observed regardless of estimation method. However, in extended experiments in Sections 4.2 and 4.3, we only report the estimation results of the FE model. As compared to POLS, the FE model can accommodate the unobserved heterogeneity of individual countries. In addition, the Hausman test results generally support the FE model rather than the RE model. As shown in Table 5, the χ^2 statistics of the Hausman test are significantly different from zero in all cases except one.

Table 5: Hausman Test Results

	Equation (1)		Equation (2)	
π^{P1}	8.24^{***}	[0.004]	2.25	[0.324]
π^{P2}	3.34^{*}	[0.067]	7.23^{**}	[0.027]
π^{P3}	6.46^{**}	[0.011]	4.61^{**}	[0.099]

Notes: 1. The null hypothesis is that the RE coefficients are consistent.
2. The numbers in brackets are p-values, and the symbols *, **, and *** indicate that the null hypothesis is rejected at the 10%, 5%, and 1% level, respectively.

4. Extended Experiments

4.1. Inflation Targets and Inflation Forecasts

We have investigated the relation between past inflation rates and inflation targets in Section 3. However, to reduce the gap between inflation targets and actual inflation rates, forward-looking central banks may set their inflation targets close to inflation forecasts for the target horizon instead of simply using past inflation rates. For example, the central bank may set the inflation target for the following year at the expected inflation rate of the following year. In this way, the actual inflation rate for the following year may be expected to be close to the inflation target. In this section, we explore the relation between inflation forecasts and inflation targets.

We replace past inflation rates with inflation forecasts for time *t* formed at time *t-1* and then estimate equations (1) and (2) again to examine whether the inflation forecast for time *t* formed at time *t-1* can explain the target at time *t*. Forecast horizons are better to be matched with target horizons, but we only use the one-year-ahead forecast because of the limited data availability. We use data from the World Economic Outlook database of the IMF and consider the period from 1999 when the time series of IMF inflation forecasts start.[8]

Table 6 shows the estimation results that use inflation forecasts. The estimated coefficients are significant and positive at the 1% level in all cases and are even larger than

[8] We use the September/October World Economic Outlook database of the IMF which presents only one-year-ahead inflation forecasts until 2007. We excluded Czech Republic and Hungary because data are not available.

those for previous inflation rates that were reported in Section 3. In equation (1), the point estimates range from 0.86 to 0.90 which are larger than the 0.43–0.54 of previous inflation rates. In equation (2), the point estimates range from 0.38 to 0.51 which are again larger than the 0.17–0.31 for past inflation rates. These results further support evidence of the endogeneity of the inflation target.

Table 6: Estimation Results Using Inflation Forecasts

	Equation (1)			**Equation (2)**		
	π^*			π^*		
	POLS	**FE**	**RE**	**POLS**	**FE**	**RE**
$const$	0.141 [0.229]	-0.037 [0.307]	0.141 [0.229]	0.893*** [0.192]	1.293*** [0.242]	0.941*** [0.212]
π^*_{-1}				0.201*** [0.055]	0.247*** [0.057]	0.220*** [0.054]
$E_{-1}(\pi)$	**0.861***** **[0.031]**	**0.891***** **[0.046]**	**0.861***** **[0.031]**	**0.505***** **[0.064]**	**0.389***** **[0.074]**	**0.469***** **[0.065]**
Observations	105	105	105	98	98	98
R^2	0.882	0.812		0.872	0.797	

Notes: The numbers in brackets are standard errors, and the symbols *, **, and *** indicate that the estimates are significant at the 10%, 5%, and 1% level, respectively.

4.2. Robustness

In this section, we examine the robustness of the results by extending the model in various directions. First, we restrict the sample period to the explicit inflation-targeting period only. As mentioned in Section 2, some countries such as Chile, Colombia, Indonesia, and Peru implicitly adopted inflation targeting before they did so explicitly. The estimation results are displayed in Table 7. The results are qualitatively similar to the baseline case, the sample of which also includes implicit inflation targeting period. The results show that the inflation target still significantly responds to the previous inflation rate. In equations (1) and (2), estimates of the coefficient of the previous inflation rate are significantly different from zero at the 1% significance level. In addition, the sizes of the estimates which range between 0.431 and 0.496 in Equation (1) and between 0.244 and 0.344 in Equation (2) are similar to those for the whole inflation targeting period.

Table 7: Explicit Inflation Targeting Period of Equations (1) and (2)

	Equation (1)			Equation (2)		
	π^*			π^*		
$const$	2.056*** [0.252]	1.563*** [0.261]	2.003*** [0.265]	1.258*** [0.263]	1.309*** [0.262]	1.263*** [0.269]
π^*_{-1}				0.371*** [0.059]	0.229*** [0.078]	0.363*** [0.063]
π^{P1}	**0.438***** [0.038]			**0.245***** [0.042]		
π^{P2}		**0.496***** [0.038]			**0.344***** [0.060]	
π^{P3}			**0.431***** [0.039]			**0.244***** [0.046]
Observations	140	140	140	127	127	127
R^2	0.526	0.582	0.506	0.630	0.627	0.614

Notes: 1. The numbers in brackets are standard errors, and the symbols *, **, and *** indicate that the estimates are significant at the 10%, 5%, and 1% level, respectively.
2. π^{P1} is the inflation rate of the previous year, π^{P2} is the average inflation rate of the past two years, and π^{P3} is the average inflation rate for the previous target horizon.

We then estimate the following model to analyze whether central banks systematically adjust their inflation target when inflation rates miss the target in the previous period. Equation (3) is obtained when the restriction $\beta_1 + \beta_2 = 1$ is imposed in equation (2):

$$\pi^*_{it} - \pi^*_{it-1} = \gamma_0 + \gamma_1(\pi^P_{it} - \pi^*_{it-1}) + \varepsilon_{it}. \qquad (3)$$

The regression measures how the inflation target changes from the previous period in respond to the deviation of the inflation rate from the target in the previous year.

Table 8 shows the estimation results. The estimated coefficients are significant at the 1% level in all cases. These results are consistent with the idea that when an inflation rate deviates from a target, central banks tend to adjust the target of the next period in such a way to possibly reduce inflation rate deviation from the target.

Table 8: Equation (3) Estimation Results

	$\Delta\pi^*$		
$const$	-1.206*** [0.200]	-1.241*** [0.209]	-1.253*** [0.204]
$\pi^{P1} - \pi^*_{-1}$	**0.194***** [0.070]		
$\pi^{P2} - \pi^*_{-1}$		**0.143**** [0.057]	
$\pi^{P3} - \pi^*_{-1}$			**0.211***** [0.072]
Observations	161	161	161
R^2	0.052	0.043	0.057

Notes: 1. The numbers in brackets are standard errors, and the symbols *, **, and *** indicate that the estimates are significant at the 10%, 5%, and 1% level, respectively.
2. π^{P1} is the inflation rate of the previous year, π^{P2} is the average inflation rate of the past two years, and π^{P3} is the average inflation rate for the previous target horizon.

Until now, we analyze the effects of inflation rates on inflation targets. However, an inflation target may also affect an actual inflation rate as is originally intended by a successful inflation-targeting regime. To control for such an effect of an inflation target on actual inflation rate, system estimation is conducted by additionally considering the following equation:

$$\pi_{it} = \delta_0 + \delta_1\pi^*_{it} + \delta_2\pi^P_{it} + \varepsilon_{it}, \quad (4)$$

where current inflation target is allowed to affect current inflation rate, and the previous inflation rate is allowed to affect the current inflation rate.

The system of Equations (2) and (4) is estimated by using the three-stage least squares (3SLS) method. Table 9 reports the estimation results.

Table 9: System Estimation Results of Equations (2) and (4)

	Equation (2)				Equation (4)		
		π^*				π	
$const$	-0.011 [0.712]	0.917 [0.819]	0.837 [0.809]	$const$	0.539 [1.196]	-0.292 [1.005]	-0.101 [1.293]
π^*_{-1}	0.207** [0.100]	0.458*** [0.052]	0.190* [0.099]	π^*	0.819*** [0.058]	0.579*** [0.046]	0.808*** [0.054]
π^{P1}	**0.399***** [0.089]			π^{P1}	0.247*** [0.037]		
π^{P2}		**0.168***** [0.042]		π^{P2}		0.478*** [0.028]	
π^{P3}			**0.421***** [0.090]	π^{P3}			0.249*** [0.036]
Observations	161	161	161	Observations	161	161	161
R^2	0.898	0.894	0.897	R^2	0.891	0.932	0.899

Notes: 1. The numbers in brackets are standard errors, and the symbols *, **, and *** indicate that the estimates are significant at the 10%, 5%, and 1% level, respectively.
2. The models are estimated using the 3SLS method.
3. π^{P1} is the inflation rate of the previous year, π^{P2} is the average inflation rate of the past two years, and π^{P3} is the average inflation rate for the previous target horizon.

The results still show that inflation performance significantly affects the inflation target of the next period. Interestingly, considering the effect of an inflation target on the current inflation rate even increases the size of the estimated coefficient of the past inflation rates except when the average inflation rates of the two previous years are used. The estimates of the coefficients of past inflation rates increase from 0.297 to 0.399 and from 0.304 to 0.421 in the first and third cases, respectively.

Finally, Equation (2) is a variant of the dynamic panel model. We use the GMM method that resolves the problem of correlation between the dependent variable and the error term. The results are qualitatively similar, as reported in Tables A2, A3, and A4 in the Appendix.

4.3. Central Bank Performance

In this study, we find that central banks tend to respond to past inflation rates when setting their inflation target, that is, the endogeneity of inflation target. Then, an important question is why such endogeneity exists.[9] In the introduction, we discuss the possibility that a central bank sets its inflation target by tracking past inflation rates to maintain its reputation under the pressure of hitting target ranges. In this case, we may observe strengthened endogeneity among central banks that have a weak reputation or performance. In other words, when a central bank has a relatively weak inflation targeting performance, it is likely to have some incentive to improve its reputation by changing the inflation target, thereby reducing the gap between the target and the actual inflation rate. In this section, we examine the relation between central bank performance and the degree of endogeneity of the inflation target.

We use this central bank performance indicator in the analysis:

$$performance\ indicator = (\pi_t - \pi_t^*)^2, \tag{5}$$

where π_t and π_t^* are actual inflation rate and the inflation target, respectively. In equation (5), a high (low) value of the indicator represents the weak (strong) performance of a central bank that tries to keep the inflation rate close to the target.

This performance indicator is closely related to central bank credibility. The definition of the indicator is consistent with the common notion that "credibility means that your pronouncements are believed" (Blinder (1998)). Recently, Bordo and Siklos (2014, 2015a, 2015b) have expressed the credibility of a central bank as the squared differential between the observed inflation rate and the target of the central bank, similar to Equation (5). Bordo

[9] With respect to their upward adjustment of the inflation target in 2005 discussed in the introduction, the Bank of Indonesia (2007) claimed that the assumptions at the time during which the inflation targets were set did not coincide with the actual condition and that the inflation targets had to be re-evaluated. However, the Bank of Indonesia has been criticized to have made actual decisions that did not reflect the commitment to an inflation targeting framework (McLeod (2008)).

and Siklos (2014, 2015a, 2015b) also estimate the "implied inflation objective" from the monetary policy rule, such as the Taylor Rule, as proxy for π_t^*. However, the current study uses the exact inflation target data that central banks have announced because we only consider cases of countries that have explicitly announced adoption of inflation targeting.

We compute the average of the performance indicator after the adoption of inflation targeting by each country using their monthly inflation data. We then classify 19 countries into two groups based on the average values of their performance indicator. The high performance group includes Canada, Chile, Czech Republic, Israel, Korea, New Zealand, Peru, the Philippines, Poland, and Thailand, whereas the low performance group includes Brazil, Colombia, Ghana, Guatemala, Hungary, Indonesia, Mexico, Romania, and Turkey. Detailed information about the indicator values and the classification of countries is shown in Table A5 of the Appendix.

Tables 10 and 11 present the estimation results of each group for equations (1) and (2), respectively, which show that in both groups, past inflation rates have a positive effect on the inflation target of the next period. Interestingly, the estimated coefficient is larger in all cases in the low performance group than in the high performance group. In addition, the estimated coefficients are significantly different from zero in all cases of the low performance group, but not in one case of the high performance group. These results suggest that past inflation rates affect inflation targets more strongly in the low performance group than in the high performance group. In other words, we find strong inflation target endogeneity in central banks with low reputation or weak performance.

Table 11 shows the estimation results for Equation (3). The difference between the two groups is more clear. In the low performance group, the estimated coefficients are positive and significant in all cases. However, no cases exist in the high performance group in which the estimated coefficients are positive and significant.

Table 10: The Role of Targeting Performance: Equation (1)

	Countries with High Performance			Countries with Low Performance		
	π^*			π^*		
$const$	2.326*** [0.241]	2.577*** [0.269]	2.258*** [0.248]	2.449*** [0.777]	2.312*** [0.829]	2.300*** [0.799]
π^{P1}	**0.411***** [0.028]			**0.515***** [0.057]		
π^{P2}		**0.327***** [0.027]			**0.509***** [0.060]	
π^{P3}			**0.410***** [0.029]			**0.521***** [0.058]
Observations	88	88	88	92	92	92
R^2	0.733	0.654	0.727	0.498	0.469	0.492

Notes: 1. The numbers in brackets are standard errors, and the symbols *, **, and *** indicate that the estimates are significant at the 10%, 5%, and 1% level, respectively.

2. π^{P1} is the inflation rate of the previous year, π^{P2} is the average inflation rate of the past two years, and π^{P3} is the average inflation rate for the previous target horizon.

Table 11: The Role of Targeting Performance: Equation (2)

	Countries with High Performance			Countries with Low Performance		
	π^*			π^*		
$const$	1.060*** [0.259]	1.041*** [0.288]	1.046*** [0.255]	1.479*** [0.351]	1.320*** [0.369]	1.377*** [0.361]
π^*_{-1}	0.455*** [0.091]	0.552*** [0.106]	0.430*** [0.092]	0.286*** [0.071]	0.381*** [0.060]	0.288*** [0.074]
π^{P1}	**0.191***** [0.067]			**0.325***** [0.059]		
π^{P2}		**0.086** [0.063]			**0.252***** [0.050]	
π^{P3}			**0.213***** [0.069]			**0.329***** [0.062]
Observations	78	78	78	83	83	83
R^2	0.800	0.782	0.804	0.847	0.840	0.843

Notes: 1. The numbers in brackets are standard errors, and the symbols *, **, *** indicate that the estimates are significant at the 10%, 5%, and 1% level, respectively.

2. π^{P1} is the inflation rate of the previous year, π^{P2} is the average inflation rate of the past two years, and π^{P3} is the average inflation rate for the previous target horizon.

Table 12: The Role of Targeting Performance: Equation (3)

	Countries with High Performance			Countries with Low Performance		
	$\Delta\pi^*$			$\Delta\pi^*$		
$const$	-0.771*** [0.164]	-0.638*** [0.167]	-0.778*** [0.165]	-1.694*** [0.377]	-1.823*** [0.370]	-1.770*** [0.389]
$\pi^{P1} - \pi^*_{-1}$	**0.036** [0.089]			**0.241**** [0.099]		
$\pi^{P2} - \pi^*_{-1}$		**-0.158**** [0.065]			**0.248***** [0.080]	
$\pi^{P3} - \pi^*_{-1}$			**0.050** [0.093]			**0.259**** [0.103]
Observations	78	78	78	83	83	83
R^2	0.002	0.081	0.004	0.075	0.116	0.079

Notes: 1. The numbers in brackets are standard errors, and the symbols *, **, and *** indicate that the estimates are significant at the 10%, 5%, and 1% level, respectively.

2. π^{P1} is the inflation rate of the previous year, π^{P2} is the average inflation rate of the past two years, and π^{P3} is the average inflation rate for the past target horizon.

Lastly, we divide the 19 countries into two groups based on their average inflation rates during the sample period because a low (high) average inflation rate may indicate good (bad) performance of central banks. Detailed information about the average inflation rates and the classification of countries is shown in Table A5 of the Appendix. With this grouping method, we find results similar to those in which countries were divided on the basis of the performance indicator in equation (5) (Tables A6–A7 in the appendix). The estimated coefficients are higher and more significant in the high inflation group than in the low inflation group.

5. Theoretical Illustration

This section illustrates the consequences of the endogeneity of the inflation target by constructing a simple, flexible price model, such as that in the study of Leeper (1991). Each individual is endowed with exogenous income in each period. Fiat money and real money balance that provides utility also exist. For simplicity, we assume a log utility function in which consumption and real money balance are separable. Each individual maximizes his or her lifetime utility depending on his or her intertemporal budget constraint. Income consists of endowments (Y_t) and gross interest income receipts from one-period government bond holdings, that is, $R_{t-1}B_{t-1}/P_t$, where B_{t-1} represents one-period nominal government bond holdings, P_t is the price level, and R_{t-1} is the gross interest rate of the bonds. An individual allocates his or her income to consumption (C_t), changes in money holdings ($(M_t-M_{t-1})/P_t$), and nominal government bond holdings after paying the government a net lump sum tax or transfer if negative (τ_t). Each individual chooses C_t, M_t, and B_t given P_t, Y_t, and τ_t:

$$\max_{\{C_t,M_t,B_t\}} E_t\left[\sum_{t=0}^{\infty}\beta^t\left(logC_t + log\frac{M_t}{P_t}\right)\right] \qquad \text{s.t.}$$

$$C_t + \frac{M_t - M_{t-1}}{P_t} + \frac{B_t - R_{t-1}B_{t-1}}{P_t} + \tau_t = Y_t, \qquad (6)$$

where $M_t \geq 0$, $B_t \geq 0$, $log\,Y_t = log\bar{Y} + \varepsilon_{y,t}$, $\varepsilon_{y,t}$ is an i.i.d. process with $E_{t-1}(\varepsilon_{y,t})=0$, $var(\varepsilon_{y,t}) = \sigma_y^2$, and $log(Y_0)$ is given.

The first-order conditions of the consumer optimization problem are:

$$\frac{C_t P_t}{M_t} = 1 - R_t^{-1} \qquad (7)$$

$$R_t^{-1} = \beta E_t\left[\frac{C_t}{C_{t+1}\widetilde{\pi}_{t+1}}\right], \qquad (8)$$

where $\widetilde{\pi}_{t+1} = P_{t+1}/P_t$.

The government issues debt and money and collects lump sum (net) tax or transfer if negative:

$$\frac{M_t - M_{t-1}}{P_t} + \frac{B_t - R_{t-1}B_{t-1}}{P_t} + \tau_t = 0. \quad (9)$$

From private and government budget constraints, the social resource constraint is

$$Y_t = C_t. \quad (10)$$

The monetary authority is assumed to set the (net) interest rate in response to the deviation of the current inflation rate (π_t) from the inflation target (π_t^*):

$$r_t = \rho_0 + \rho(\pi_t - \pi_t^*) + \varepsilon_{m,t}, \quad (11)$$

where $0 \leq \rho$, r_t is net interest rate, π_t is inflation rate, and $\varepsilon_{m,t}$ is an i.i.d process with $E_{t-1}(\varepsilon_{m,t}) = 0$, and $var(\varepsilon_{m,t}) = \sigma_m^2$.[10]

In equation (8), we replace the Ys with Cs using equation (10) and then linearize the equation around the steady state to obtain the following equation:

$$E_t\pi_{t+1} - r_t = \varepsilon_{y,t}. \quad (12)$$

In the present model, the equilibrium inflation rate can be calculated using equations (11) and (12). When the inflation target is exogenously determined, a unique equilibrium exists when $\rho > 1$, as discussed in past studies such as that of Leeper (1991). When $\rho < 1$, the equilibrium is undetermined. When the inflation rate exceeds the inflation target, the monetary authority should increase the nominal interest rate more than the inflation rate rise to increase the real rate and stabilize the inflation rate. When $\rho > 1$, the unique solution for the inflation rate is as follows:

[10] Fiscal policy is assumed to satisfy government budget constraints. In other words, fiscal policy is "passive," as defined by Leeper (1991).

$$\pi_t = \rho^{-1}(\varepsilon_{y,t} - \varepsilon_{m,t}) + \pi_t^* . \text{[11]} \tag{13}$$

The variance of the inflation rate is:

$$var(\pi_t) = \rho^{-2}(\sigma_y^2 + \sigma_m^2) + var(\pi_t^*). \tag{14}$$

We now consider two cases of the endogeneity of the inflation target. First, the inflation target depends on the past inflation rate, that is,

$$\pi_t^* = \phi_0 + \phi\pi_{t-1}, \tag{15}$$

where $0 \leq \phi \leq 1$. When $\phi = 0$, the inflation target does not depend on the past inflation rate, and when $\phi = 1$, the inflation target fully depends on the past inflation rate. When $0 < \phi < 1$, the inflation target partially depends on the past inflation rate. Second, the inflation target at time *t* depends on the expected inflation rate for time *t* which is formed at time *t-1*:

$$\pi_t^* = \varphi_0 + \varphi E_{t-1}(\pi_t), \tag{16}$$

where $0 \leq \varphi \leq 1$.

The inflation dynamics in the first case is described in the following equation:

$$\pi_t = \rho^{-1} E_t \pi_{t+1} + \phi\pi_{t-1} + \rho^{-1}(\varepsilon_{y,t} - \varepsilon_{m,t}). \tag{17}$$

When the inflation target fully depends on the past inflation rate ($\phi = 1$), a unique equilibrium does not exist and equilibrium is undetermined regardless of ρ value. For instance, if the economy was initially in a steady state with the inflation rate and the target at the 3% level and the inflation rate increases to 4%, then the inflation target also increases to 4% in the next period. Therefore, the monetary authority does not need to increase the

[11] We also linearize equation (11) around the steady state. Thus, ρ_0 does not appear in the solution.

interest rate to stabilize the inflation rate; the inflation rate stays at 4%. In other words, once the inflation rate rises or decreases to any new level, it stays at that level, and no mechanism exists for moving the inflation rate back to the initial level. Therefore, a unique equilibrium does not exist and equilibrium is undetermined.

When $0 \leq \phi < 1$, a unique equilibrium exists when $\rho\phi + 1 < \rho$ or $1/(1-\phi) < \rho$. When $\phi = 0$, the condition reverts to the previous $1 < \rho$. As ϕ increases, ρ also needs to increase to be able to attain unique equilibrium. If the economy was initially in a steady state with the inflation rate and the target at the 3% level and the inflation rate increases to 4%, then the inflation target also increases in the next period to 3.5%, for example, when $\phi = 0.5$. In this case, the monetary authority needs to increase the nominal interest rate by more than 1 to 1 (that is, more than 1%) in response to *the gap between the current inflation rate (4%) and the initial inflation rate (3%)* to increase the real interest rate and stabilize the inflation rate. However, increasing the nominal interest rate by more than 1 to 1 (that is, more than 0.5%) in response to *the gap between the current inflation rate (4%) and the target inflation rate (3.5%)* is not enough to increase the real rate and stabilize the inflation rate. Thus, the monetary authority now needs to increase the nominal interest rate by more than 2 (=1/(1-ϕ)) to 1 (that is, more than 1%) in response to *the gap between the current inflation rate and the target inflation rate.*

When $1/(1-\phi) < \rho$, the unique solution for the inflation rate is as follows:

$$\pi_t = \lambda_1 \pi_{t-1} + (1 - \lambda_1 / \rho)\rho^{-1}(\varepsilon_{y,t} - \varepsilon_{m,t}), \tag{18}$$

where $|\lambda_1| < 1$ is the stable root of $\lambda^2 - \rho\lambda + \rho\phi = 0$. The variance of the inflation rate is:

$$\text{var}(\pi_t) = \left[\frac{1-\frac{\lambda_1}{\rho}}{1-\lambda_1}\right]^2 \rho^{-2}\left(\sigma_y^2 + \sigma_m^2\right) \tag{19}$$

The variance of the inflation rate is larger in the case of $\phi > 0$ than in the case of $\phi = 0$ because $[(1-\lambda_1/\rho)/(1-\lambda_1)]^2 > 1$. An increase in inflation rate increases the inflation rate target in the next period, which in turn affects the actual inflation rate in that period. Thus, inflation becomes more volatile.

In the second case, inflation dynamics is described by the following equation:

$$\pi_{t} = \rho^{-1} E_{t} \pi_{t+1} + \varphi E_{t-1} \pi_{t} + \rho^{-1} (\varepsilon_{y,t} - \varepsilon_{m,t}) . \tag{20}$$

The condition for a unique equilibrium is similar to the first case. When the inflation target fully depends on the expected inflation rate (φ = 1), a unique equilibrium does not exist. When expected inflation rate increases, the monetary authority also increases the inflation target by the same amount, and the expected and actual inflation rates remain at the increased level. Therefore, no mechanism exists for moving the inflation rate back to the initial level.

When $0 \leq \varphi < 1$, a unique equilibrium exists when $\rho \varphi + 1 < \rho$ or $1/(1-\varphi) < \rho$. When $\varphi = 0$, the condition reverts to the previous $1 < \rho$. As φ increases, ρ also needs to increase to be able to attain unique equilibrium. When inflation expectation increases, the inflation target also increases. As in the first case, to stabilize inflation expectation and inflation rate, the monetary authority needs to increase the nominal interest rate in response to the gap between the current inflation rate and target inflation rate more than in response to the gap between the current inflation rate and initial inflation rate.

When $1/(1-\varphi) < \rho$, the unique solution for the inflation rate is as follows:

$$\pi_{t} = (1-\varphi)^{-1} \rho^{-1} (\varepsilon_{y,t} - \varepsilon_{m,t}) . \tag{21}$$

The variance of the inflation rate is:

$$\mathrm{var}(\pi_t) = \left[\frac{1}{1-\varphi}\right]^2 \rho^{-2}\left(\sigma_y^2 + \sigma_m^2\right) \tag{22}$$

Therefore, the variance of the inflation rate increases as φ increases. An increase in actual and expected inflation rate affects the inflation target, which in turn affects the actual and expected inflation rate. Thus, inflation becomes more volatile.[12]

6. Conclusion

This study empirically investigates whether an inflation target is set in response to past or expected inflation rates in 19 inflation-targeting countries. The empirical results show that the inflation target of many central banks significantly and positively respond to past or expected inflation rates. This result is found through various methods, such as the Granger causality test, correlation analysis, individual country regression, and panel regression. The results of this study imply that the endogeneity of inflation targets exists. We also show that strong endogeneity is found in central banks with low credibility or weak performance, suggesting that such endogeneity may come from the incentive for a central bank to raise its reputation by reducing the deviation of an actual inflation rate from the target. Furthermore, we develop some theoretical models to show that the endogeneity of the inflation target can lead to equilibrium indeterminacy and can increase the volatility of the inflation rate.

Some future studies are necessary. First, further investigation on why some central banks change inflation targets in response to past inflation rates is important. Second, the actual consequence of this endogeneity of inflation targets should be further analyzed in each economy in which the endogeneity of inflation target has been observed.

[12] Similar results can be obtained in the standard New Keynesian model which is discussed in past studies, such as that of Clarida, Gali, and Gertler (1999). When equation (11) with the exogenous inflation target is considered as the monetary policy rule, a unique equilibrium exists when $1 < \rho$, as discussed in many past studies. When the inflation target depends on the past inflation rate as in equation (15) or on the expected inflation rate regardless of the value of ρ as in equation (16), a unique equilibrium does not exist and equilibrium is undetermined when $\phi = 1$ and $\varphi = 1$, respectively. When the expected inflation target depends on the expected inflation rate as in equation (16), a unique equilibrium exists when $1/(1-\varphi) < \rho$. When the expected inflation target depends on past inflation rate as in equation (15), the results depend on the values of parameters in the model. For some parameter regions, a unique equilibrium does not exist and equilibrium is undetermined regardless of the value of ρ. For others, a unique equilibrium exists when $1/(1-\phi) < \rho$.

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Appendix: Tables

Table A1: Changes in Inflation Targets of Inflation Targeting Countries

	Korea[2]	Thailand[2]	Philippines	Indonesia[2]	Israel[3]	Poland[4]	Czech[5]	Chile	Brazil	Colombia	Peru	Hungary[6]	Mexico	Guatemala	Romania[7]	Turkey	Ghana
1990																	
1991								15.0~20.0%		22.0%							
1992					14.0~15.0%			13.0~16.0%		22.0%							
1993					10.0%			10.0~12.0%		22.0%							
1994					8.0%			9.0~11.0%		19.0%	15.0~20.0%						
1995					8.0~11.0%			9.0%		18.0%	9.0~11.0%		42.0%				
1996					8.0~10.0%			6.5%		17.0%	9.5~11.5%		20.5%				
1997					7.0~10.0%			5.5%		18.0%	8.0~10.0%		15.0%				
1998	9.0±1.0%				7.0~10.0%		5.5~6.5%	4.5%		16.0%	7.5~9.0%		12.0%				
1999	3.0±1.0%				4.0%	8.0~8.5%	4.0~5.0%	4.3%	8.0±2.0%	15.0%	5.0~6.0%		13.0%				
2000	2.5±1.0%			5.0~7.0%	3.0~4.0%	5.4~6.8%	3.5~5.5%	3.5%	6.0±2.0%	10.0%	3.5~4.0%		10.0%				
2001	3.0±1.0%			4.0~6.0%	2.5~3.5%	6.0~8.0%	2.0~4.0%		4.0±2.0%	8.0%	2.5~3.5%	7.0%	6.5%				
2002	3.0±1.0%		4.5~5.5%	9.0~10.0%	2.0~3.0%	4.0~6.0%	3.0~5.0%		3.5±2.0%	6.0%		4.5%	4.5%			35.0%	N.A.
2003	3.0±1.0%		4.5~5.5%	9.0±1.0%		2.0~4.0%	↓	2.0~4.0%	4.0±2.5%	5.0~6.0%		3.5%				20.0%	N.A.
2004		0.0~3.5%	4.0~5.0%	5.5±1.0%					5.5±2.5%	5.0~6.0%	2.5±1.0%	3.5%				12.0%	N.A.
2005	2.5~3.5%		5.0~6.0%	6.0±1.0%			2.0~4.0%		4.5±2.5%	4.5~5.5%		4.0%		4.0~6.0%	7.5±1.0%	8.0%	N.A.
2006			4.0~5.0%	6.0±1.0%					4.5±2.0%	4.0~5.0%		3.5%		6.0±1.0%	5.0±1.0%	5.0%	N.A.
2007			4.0~5.0%	6.0±1.0%			3.0±1.0%		4.5±2.0%	3.5~4.5%				5.0±1.0%	4.0±1.0%	4.0%	7.0~9.0%
2008	3.0±0.5%		4.0±1.0%	5.0±1.0%					4.5±2.0%	3.5~4.5%				5.5±1.5%	3.8±1.0%	4.0%	6.0~8.0%
2009		0.5~3.0%	3.5±1.0%	4.5±1.0%					4.5±2.0%	4.5~5.5%				5.5±1.0%	3.5±1.0%	7.5%	12.5~16.5%
2010			4.5±1.0%	5.0±1.0%	1.0~3.0%	2.5±1.0%			4.5±2.0%	3.0±1.0%		3.0%	3.0±1.0%	5.0±1.0%	3.5±1.0%	6.5%	9.5±2.0%
2011	3.0±1.0%		4.0±1.0%	5.0±1.0%					4.5±2.0%	3.0±1.0%				5.0±1.0%	3.0±1.0%	5.5%	9.0±2.0%
2012		0.5~3.0%		4.5±1.0%				3.0±1.0%	4.5±2.0%		2.0±1.0%			4.5±1.0%	3.0±1.0%		8.5±2.0%
2013			4.0±1.0%	4.5±1.0%			2.0±1.0%		4.5±2.0%							5.0%	9.0±2.0%
2014	2.5~3.5%			4.5±1.0%					4.5±2.0%	3.0±1.0%							9.5±2.0%
2015			3.0±1.0%	4.0±1.0%					4.5±2.0%					4.0±1.0%	2.5±1.0%		8.0±2.0%
2016		2.5±1.5%		4.0±1.0%					4.5±2.0%			3.0±1.0%				5.0%	
2017			3.0±1.0%	4.0±1.0%					4.5±1.5%								

Notes: 1. The shaded part indicates the year in which inflation targeting became official.
2. The underlined numbers indicate core inflation.
3. Israel shifted to long-term targeting in August 2000. Since 2003, inflation target has been set to 1%–3% for an indefinite period.
4. Poland shifted to continuous-time inflation targeting in 2004.
5. In the Czech Republic, the target index was net (core) inflation until 2001. Since 2002, the target index was headline inflation.
6. Hungary has adopted medium term target horizon since 2003.
7. From 2013, the phase of a flat, multi-annual, inflation-target intermediate stage meant to ensure the transition of Romania toward long-term continuous inflation targeting.

Table A1: Changes in Inflation Targets of Inflation Targeting Countries (continued)

	New Zealand	Australia	Canada	UK[2)]	Sweden	South Africa	Norway	Iceland	Armenia	Serbia	Georgia	Albania	Moldova	Japan	India
1990															
1991	0.0~2.0%		5.0%±1.0%												
1992			3.0%±1.0%												
1993															
1994	0.0~2.0%		2.5%±1.0%												
1995															
1996			1.0~3.0%												
1997	0.0~3.0%			2.5%											
1998	0.0~3.0%														
1999			1.0~3.0%												
2000															
2001	0.0~3.0%														
2002															
2003			1.0~3.0%												
2004	1.0~3.0%														
2005		2.0~3.0%			2.0%±1.0%										
2006										N.A.					
2007	1.0~3.0%									N.A.					
2008						3.0~6.0%				N.A.					
2009			1.0~3.0%				2.5%	2.5%		6.0~10.0%			9.0%±1.0%		
2010	1.0~3.0%			2.0%						6.0%±2.0%	6.0%		5.0%±1.0%		
2011									4.0%±1.5%	4.5%±1.5%			mid-single digit		
2012													5.0%±1.5%		
2013										4.0%±1.5%	6.0%	3.0%±1.0%			
2014			1.0~3.0%												
2015	1.0~3.0%									4.0%±1.5%	5.0%		5.0%±1.5%	2.0%	
2016															4.0%±2.0%
2017										4.0%±1.5%	4.0%				

Notes: 1. The shaded part indicates the year in which inflation targeting became official.
2. In the UK, the inflation target index was changed from RPIX into CPI in 2004.
Source: Central Banks, etc.

Table A2: GMM Estimation Results: Equation (2)

	First Difference GMM						System GMM					
	One-step GMM			Two-step GMM			One-step GMM			Two-step GMM		
	π^*			π^*			π^*			π^*		
$const$	1.519*** [0.175]	1.441*** [0.188]	1.473*** [0.181]	1.438*** [0.470]	1.406*** [0.474]	1.459*** [0.510]	1.486*** [0.170]	1.459*** [0.178]	1.455*** [0.173]	1.418*** [0.522]	1.355*** [0.491]	1.425*** [0.463]
π^*_{-1}	0.420*** [0.052]	0.465*** [0.048]	0.429*** [0.055]	0.416*** [0.144]	0.463*** [0.0964]	0.428** [0.201]	0.460*** [0.049]	0.491*** [0.045]	0.451*** [0.052]	0.470** [0.189]	0.491*** [0.130]	0.451*** [0.138]
π^{P1}	**0.188***** [0.042]			**0.190**** [0.090]			**0.157***** [0.039]			**0.149** [0.135]		
π^{P2}		**0.147***** [0.037]			**0.149**** [0.071]			**0.124***** [0.033]			**0.127** [0.093]	
π^{P3}			**0.183***** [0.045]			**0.184** [0.203]			**0.166***** [0.042]			**0.168** [0.127]
observations	142	142	142	142	142	142	161	161	161	161	161	161
number of instrumental variables	62	62	62	62	62	62	79	79	79	79	79	79

Notes: 1. The numbers in brackets are standard errors, and *, **, and *** indicate that the estimates are significant at the 10%, 5%, and 1% level, respectively.

2. π^{P1} is the inflation rate of the previous year, π^{P2} is the average inflation rate of the past two years, and π^{P3} is the average inflation rate of the previous target horizon.

3. The bias-corrected and robust standard errors of Windmeijer (2005) are reported in the case of two-step GMM.

Table A3: Explicit Inflation Targeting Period / GMM Estimation Results: Equation (2)

	First Difference GMM						System GMM					
	One-step GMM			Two-step GMM			One-step GMM			Two-step GMM		
	π^*			π^*			π^*			π^*		
$const$	1.609*** [0.298]	1.757*** [0.288]	1.542*** [0.298]	1.540*** [0.391]	1.669 [1.106]	1.525 [1.038]	1.593*** [0.268]	1.683*** [0.262]	1.514*** [0.270]	1.582*** [0.299]	1.718** [0.755]	1.510*** [0.343]
π^*_{-1}	0.336*** [0.070]	0.186* [0.101]	0.311*** [0.072]	0.340** [0.143]	0.168 [0.359]	0.308 [0.200]	0.377*** [0.061]	0.255*** [0.089]	0.356*** [0.063]	0.384*** [0.100]	0.222* [0.116]	0.358*** [0.113]
π^{P1}	**0.212***** [0.046]			**0.205**** [0.104]			**0.179***** [0.044]			**0.172*** [0.090]		
π^{P2}		**0.302***** [0.076]			**0.309**** [0.139]			**0.257***** [0.072]			**0.268**** [0.133]	
π^{P3}			**0.240***** [0.051]			**0.243**** [0.096]			**0.207***** [0.049]			**0.206**** [0.097]
observations	103	103	103	103	103	103	121	121	121	121	121	121
number of instrumental variables	58	58	58	58	58	58	75	75	75	75	75	75

Notes: 1. The numbers in brackets are standard errors, and *, **, and *** indicate that the estimates are significant at the 10%, 5%, and 1% level, respectively.

2. π^{P1} is the inflation rate of the previous year, π^{P2} is the average inflation rate of the past two years, and π^{P3} is the average inflation rate of the previous target horizon.

3. The bias-corrected and robust standard errors of Windmeijer (2005) are reported in the case of two-step GMM.

Table A4: The Role of Targeting Performance / GMM Estimation Results: Equation (2)

(Countries with high performance)

	First Difference GMM						**System GMM**					
	One-step GMM			**Two-step GMM**			**One-step GMM**			**Two-step GMM**		
	π^*			π^*			π^*			π^*		
$const$	0.932^{***} [0.258]	0.714^{**} [0.316]	0.935^{***} [0.253]	0.864^{***} [0.309]	0.623 [1.171]	0.828^{***} [0.320]	0.674^{***} [0.249]	0.523^{*} [0.303]	0.687^{***} [0.246]	0.650^{**} [0.282]	0.566 [0.826]	0.641^{**} [0.250]
π^*_{-1}	0.579^{***} [0.0990]	0.799^{***} [0.138]	0.554^{***} [0.102]	0.548^{**} [0.257]	0.770 [0.567]	0.531^{***} [0.183]	0.619^{***} [0.093]	0.796^{***} [0.133]	0.582^{***} [0.099]	0.551^{***} [0.094]	0.722 [0.493]	0.548^{***} [0.196]
π^{P1}	**0.093** [0.074]			**0.124** [0.220]			**0.103** [0.071]			**0.169*** [0.096]		
π^{P2}		**-0.073** [0.084]			**-0.035** [0.287]			**-0.038** [0.082]			**0.019** [0.274]	
π^{P3}			**0.114** [0.077]			**0.143** [0.166]			**0.133*** [0.076]			**0.166** [0.166]
observations	68	68	68	68	68	68	78	78	78	78	78	78
number of instrumental variables	40	40	40	40	40	40	50	50	50	50	50	50

Notes: 1. The numbers in brackets are Standard errors, and *, **, and *** indicate that the estimates are significant at the 10%, 5%, and 1% level, respectively.

2. π^{P1} is the inflation rate of the previous year, π^{P2} is the average inflation rate of the past two years, and π^{P3} is the average inflation rate of the past target horizon.

3 . The bias-corrected and robust standard errors of Windmeijer (2005) are reported in the case of two-step GMM.

(Countries with low performance)

	First Difference GMM						System GMM					
	One-step GMM			Two-step GMM			One-step GMM			Two-step GMM		
	π^*			π^*			π^*			π^*		
$const$	1.696*** [0.267]	1.474*** [0.302]	1.625*** [0.290]	1.541*** [0.583]	1.449** [0.730]	1.439 [1.171]	1.774*** [0.261]	1.682*** [0.280]	1.721*** [0.273]	1.679*** [0.525]	1.622** [0.693]	1.406 [1.618]
π^*_{-1}	0.370*** [0.061]	0.417*** [0.053]	0.393*** [0.067]	0.380** [0.184]	0.414* [0.229]	0.407 [0.420]	0.433*** [0.057]	0.466*** [0.051]	0.435*** [0.062]	0.432** [0.189]	0.464** [0.192]	0.462 [0.437]
π^{P1}	**0.236****** [0.051]			**0.223**** [0.127]			**0.177****** [0.046]			**0.174** [0.117]		
π^{P2}		**0.209****** [0.045]			**0.209** [0.144]			**0.152****** [0.039]			**0.156** [0.110]	
π^{P3}			**0.220****** [0.057]			**0.227** [0.272]			**0.178****** [0.050]			**0.186** [0.228]
observations	74	74	74	74	74	74	83	83	83	83	83	83
number of instrumental variables	49	49	49	49	49	49	66	66	66	66	66	66

Notes: 1. The numbers in brackets are standard errors, and *, **, and *** indicate that the estimates are significant at the 10%, 5%, and 1% level, respectively.

2. π^{P1} is the inflation rate of the previous year, π^{P2} is the average inflation rate of the past two years, and π^{P3} is the average inflation rate of the previous target horizon.

3. The bias-corrected and robust standard errors of Windmeijer (2005) are reported in the case of two-step GMM.

Table A5: Country Grouping

	Performance		Inflation	
Country	Indicator	Group	Average Level	Group
Thailand	1.1	High	1.1	Low
Canada	1.1	High	1.9	Low
Korea	1.7	High	2.9	Low
Peru	2.7	High	4.1	Low
New Zealand	3.0	High	2.3	Low
Philippines	3.8	High	4.1	Low
Poland	3.8	High	3.1	Low
Czech Republic	4.1	High	1.9	Low
Israel	6.0	High	4.4	Low
Chile	6.4	High	5.8	High
Hungary	6.5	Low	4.6	Low
Romania	6.6	Low	5.0	High
Colombia	8.1	Low	11.0	High
Guatemala	8.5	Low	5.5	High
Indonesia	12.0	Low	7.2	High
Brazil	12.7	Low	6.6	High
Ghana	27.6	Low	13.1	High
Mexico	29.1	Low	9.5	High
Turkey	40.4	Low	12.1	High
Average	6.9	-	5.6	-

Note: "High" and "Low" correspond to high and low performance or inflation groups, respectively.

Table A6: Low Inflation versus High Inflation Countries: Equation (1)

	Countries with Low Inflation			Countries with High Inflation		
	π^*			π^*		
$const$	2.426*** [0.227]	2.593*** [0.230]	2.333*** [0.235]	2.385*** [0.740]	2.235*** [0.793]	2.281*** [0.757]
π^{P1}	**0.351***** [0.029]			**0.530***** [0.053]		
π^{P2}		**0.278***** [0.025]			**0.524***** [0.056]	
π^{P3}			**0.352***** [0.030]			**0.533***** [0.054]
Observations	83	83	83	97	97	97
R^2	0.668	0.637	0.663	0.535	0.503	0.527

Table A7: Low Inflation versus High Inflation Countries: Equation (2)

	Countries with Low Inflation			Countries with High Inflation		
	π^*			π^*		
$const$	1.262*** [0.288]	1.314*** [0.316]	1.241*** [0.283]	1.442*** [0.331]	1.289*** [0.348]	1.366*** [0.340]
π^*_{-1}	0.436*** [0.096]	0.471*** [0.114]	0.403*** [0.100]	0.275*** [0.069]	0.375*** [0.058]	0.283*** [0.071]
π^{P1}	**0.149**** [0.066]			**0.344***** [0.057]		
π^{P2}		**0.089** [0.062]			**0.262***** [0.048]	
π^{P3}			**0.179**** [0.071]			**0.341***** [0.060]
Observations	73	73	73	88	88	88
R^2	0.684	0.669	0.690	0.862	0.855	0.858

Notes: 1. The numbers in brackets are standard errors, and *, **, and *** indicate that the estimates are significant at the 10%, 5%, and 1% level, respectively.
2. π^{P1} is the inflation rate of the previous year, π^{P2} is the average inflation rate of the past two years, and π^{P3} is the average inflation rate of the past target horizon.