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Do Inflation-Targeting Central Banks Adjust Inflation Targets to Meet the Target?[†]

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Abstract

Under inflation targeting, central banks are supposed to set an inflation target in advance and then try to make the actual inflation reach the target. However, central banks may have an incentive to adjust their targets to meet their goals. Panel data analysis with a sample of 19 inflation-targeting countries show that changes in the inflation target significantly and positively respond to the deviation of the inflation rate from the target in the previous period. This result supports the idea that inflation-targeting central banks adjust the inflation target to meet the target when they miss it. Further analysis suggests that such a relationship is more evident in central banks with low credibility or weak performance compared with high credibility or strong performance. Finally, we show that such behavior of central banks can lead to equilibrium indeterminacy in the standard New Keynesian model. Further, such behavior renders achieving equilibrium determinacy harder for central banks even in more realistic models. This result may imply that when central banks respond to missed inflation targets by adjusting their targets and to enhance the credibility and stabilize the inflation rate, they may end up destabilizing inflation expectations and the inflation rate.

Keywords: Inflation Targeting, Inflation Rate, Inflation Target, New Keynesian Model, Indeterminacy
JEL Classifications: E31, E58

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1. Introduction

Since New Zealand adopted inflation targeting in 1990, an increasing number of countries have adopted this policy as well. As a result, actual inflation rates in many economies, even emerging ones, have decreased sharply after the inflation targeting system was introduced. The inflation rate in our sample of 19 countries dropped by 9.3% points on average in 5 years after adopting inflation targeting.

Although inflation targeting has been successful in reducing the inflation rate, the inflation-targeting central banks have not always been successful in meeting the inflation target. In our sample of 19 countries, the absolute value of deviation of the actual inflation rate from the target is 2.0% points at an annual average. This study aims to find out how inflation-targeting central banks behave when they miss the target. Particularly, do inflation-targeting central banks respond to misses on their targets by adjusting their targets to close the gap between the actual inflation rate and the inflation target?

For example, in 2004, the Bank of Indonesia set the following three-year inflation target: 6 ± 1% (2005), 5.5 ± 1% (2006), and 5 ± 1% (2007). However, when the inflation rate departed from the upper bound of the target (10.5% in 2005), the Bank of Indonesia revised upwards the mid-point of the target by more than 1% point to 8 ± 1% (2006), 6 ± 1% (2007), and 5 ± 1% (2008) in 2005.

Similarly, the Central Bank of Colombia decreased the annual inflation target gradually from 22% (1993) to 17% (1996) when the inflation rate declined from 27% (1992) to 20.9% (1995). However, the central bank raised the target by 1% point to 18% in 1997 because the inflation rate did not substantially drop in 1996 (20.8%) and exceeded the inflation target by 3.8% points. However, the central bank lowered the target to 16% in 1998 after confirming that the inflation rate decreased to 18.5%; the difference between the actual inflation rate and the target shrank to 0.5% point in 1997. Conversely, in 1999, the inflation rate suddenly dropped to 10.9% from 18.7% in the previous year and fell short of the target by 4.1% points. The bank revised the target downward by 5% points from 15% (1999) to 10% (2000) in this case. Moreover, the Central Bank of Colombia adjusted its target rate even in recent years because the inflation rate deviated from the target substantially. As the inflation rate sharply increased from 5.5% in 2007 to 7% in 2008, missing the target by 3% points, the central bank

revised the target upward by 1% point from 3.5%–4.5% (2008) to 4.5%–5.5% (2009). The inflation rate then dropped in 2009 (4.2%), causing the target to be missed by –0.8% points. Subsequently, the target for 2010 was reduced to 3 ± 1%.

Under inflation targeting, central banks often face immense pressure to keep 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 the next period. In other words, central banks ideally set an inflation target first and then make the actual inflation rate adjust to the target. However, central banks may adjust an inflation target to the actual inflation rate instead, especially when meeting the target is difficult.

With such behavior, inflation targeting may seem successful even when it is not because the actual inflation rate is close to the target. More importantly, such behavior may weaken the stabilizing role of an inflation targeting framework. Under the inflation targeting framework, the central bank is supposed to help stabilize inflation by setting the target, trying to achieve the target, showing effort to economic agents, and leading economic agents to set inflation expectations close to the target. However, if the central bank changes the target to close the gap between the target and the actual rate, then the inflation expectations of economic agents and the actual inflation rates may not be stabilized because deviations of the inflation rate from the target will be resolved by adjustment of the target and not by changes in actual inflation rate with monetary policy actions. In this case, the inflation target adjusts to the inflation rate; therefore, the inflation target may not work as an anchor for the inflation expectations of economic agents.

We run panel regressions by using the data of 19 inflation-targeting countries. The empirical results suggest that the adjustment of inflation targets from the previous period significantly and positively depend on the deviations of the actual rate from the target. In other words, when central banks miss the target, the central banks adjust their inflation target in the next period to close the gap between the actual rate and the target, given the high persistence of the inflation rate. 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, namely, high- and

low-performance groups, based on the performance of their central banks in meeting the inflation target. The results show that countries in the low-performance group actively adjust inflation targets to meet the target compared with 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 construct a standard New Keynesian model to illustrate the consequences of the behaviors of central banks. We show that equilibrium is undetermined under such behavior, and thus reveal an ironic result. When the actual inflation rate deviates from the inflation target, but the inflation target is difficult to achieve, central banks may consider adjusting the inflation target to close the gap between the actual inflation rate and the target in the next period. This action aims to enhance the credibility and stabilize the inflation rate but ends up with equilibrium indeterminacy by destabilizing the inflation expectation and the inflation rate.

The rest of our paper is organized as follows: Section 2 explains the data and presents the empirical results. Section 3 provides the standard New Keynesian model to illustrate the consequences of central banks' adjustment of inflation targets to meet the target. Section 4 concludes the study with a summary of the results.

2. Empirical Analysis

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.[2] Although the International Financial Statistics (IFS) of the

[2] 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 explicit and implicit targeting periods because the explicit inflation targeting period is often short and we hope to observe the entire phenomenon of inflation targeting. Chile, Colombia, Ghana,

International Monetary 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 Consumer Price Index (CPI) and inflation target data, are difficult to obtain from IFS. Some omitted values were also collected from IMF country reports and from the study by Mishkin and Savastano (2002).

Using the collected inflation rate and target data, we calculate the degree of target adjustment in certain periods and the miss on the target in the immediately preceding years. We measure the degree of target adjustment as the change in the mid-points of inflation targets between a certain inflation-targeting period and its previous inflation-targeting period. To generate the data of the miss on the target in the immediately preceding years, we subtract the mid-point of inflation target in the previous targeting period from the past inflation performance of the immediately preceding years. The past inflation performance is calculated in three ways: inflation rate of the previous year, average inflation rate of the past two years, and average inflation rate of the previous years, the length of which corresponds to the current targeting period. For example, if the inflation-targeting period is set to three years from 2013 to 2015, then the average of the mid-point of inflation target in previous targeting period is subtracted from the inflation rate in 2012, the average inflation rate from 2011 to 2012, and the average inflation rate from 2010 to 2012. In the last case, the length of the period during which this study measures the inflation performance does not exceed three years.

2.2. Panel Regression

To investigate whether central banks systematically adjust their inflation target when inflation rates miss the target in the previous period to meet the target, we estimate the following panel regression model:

Indonesia, Mexico, Peru, and Turkey implicitly indicate their inflation target because they are not sure whether they possess 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 because data on its implicit inflation targeting period are not available. An analysis on the sample of only explicit inflation targeting periods is conducted to check the robustness of the 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.

$$\pi_{it}^{*} - \pi_{it-1}^{*} = \alpha_0 + \alpha_1(\pi_{it}^{P} - \pi_{it-1}^{*}) + \varepsilon_{it}, \quad (1)$$

where π_{it}^{*} (π_{it-1}^{*}) is the mid-point value of the inflation target in the current (previous) targeting period, π_{it}^{P} is the inflation performance in the immediately preceding years, and ε_{it} is an error term. In the following tables, we denote inflation rate of the previous year by π_{it}^{P1}, average inflation rate of the past two years by π_{it}^{P2}, and average inflation rate of the previous years, the length of which corresponds to the current targeting period by π_{it}^{P3}. The regression measures how the inflation target changes from the previous period respond to the deviation of the inflation rate from the target in the previous period. When the inflation rate is persistent, adjustments in the inflation target are likely to decrease the gap between the target and the actual rate.

Table 1 shows the estimation results for Equation (1) using fixed effects (FE) and random effects (RE) models. The estimates of coefficient α_1 are significantly different from zero and positive, except when we calculate the miss on the target using the average inflation rate of the past two years in the RE model. The size of the significantly estimated coefficients ranges from 0.14 to 0.21. The 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 to possibly reduce the inflation rate deviation from the target.

To roughly assess how large adjustments in the inflation target are due to past deviations from the target, we use the average of the absolute value of the deviation of actual inflation rate from the target during the sample period (2.1% points) and the estimated coefficient of 0.194 in Table 1. By multiplying two numbers (2.1% points × 0.194), we obtain 0.41% point. Therefore, during the sample period, 0.41% point of the target adjustment is explained by past deviations from the target on average, which is a non-trivial number.

Table 1: Estimation Results

FE	**RE**
$\Delta\pi^{*}$	$\Delta\pi^{*}$

$const$	-1.206^{***}	-1.241^{***}	-1.253^{***}	-1.167^{***}	-1.117^{***}	-1.190^{***}
	[0.200]	[0.209]	[0.204]	[0.291]	[0.252]	[0.284]
$\pi^{P1} - \pi^{*}_{-1}$	**0.194*****			**0.141****		
	[0.070]			[0.069]		
$\pi^{P2} - \pi^{*}_{-1}$		**0.143****			**0.056**	
		[0.057]			[0.057]	
$\pi^{P3} - \pi^{*}_{-1}$			**0.211*****			**0.139***
			[0.072]			[0.072]
Observations	161	161	161	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 of the previous years, the length of which corresponds to the current targeting period.

Although a significant and positive relationship is observed not only in the FE model, but also in the RE model in Table 1, we henceforth focus on the estimation results of the FE model based on Hausman test results, reported in Table 2. The Hausman test results generally support the FE model rather than the RE model. The χ^2 statistics of the Hausman test are significantly different from zero regardless of which measure is used to calculate the past inflation performance.

Table 2: Hausman Test Result

$\pi^{P1} - \pi^{*}_{-1}$	$\pi^{P2} - \pi^{*}_{-1}$	$\pi^{P3} - \pi^{*}_{-1}$
7.31^{***} [0.007]	17.49^{***} [0.000]	10.05^{***} [0.002]

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.

We obtain qualitatively similar results when we restrict the sample period to the explicit inflation-targeting period only. As mentioned in footnote 2, some countries, such as Chile, Colombia, Indonesia, and Peru, implicitly adopted inflation targeting before they did so explicitly. The estimation results of the FE model are displayed in Table 3. The estimated coefficients are still significantly different from zero and positive at 1%

level in all cases. The sizes of the estimates, which ranges from 0.28 to 0.33, are even larger than that of the baseline case. These results indicate a tendency of central banks to change the inflation targets to correct their misses, and such a tendency is strengthened after the inflation-targeting regimes are implemented explicitly. When the inflation-targeting regime is implemented explicitly, central banks have more pressure to meet their targets.

Table 3: Estimation Results for Explicit Inflation Targeting Period

	$\Delta\pi^*$		
$const$	–0.685*** [0.123]	–0.807*** [0.146]	–0.732*** [0.131]
$\pi^{P1} - \pi^*_{-1}$	**0.290***** [0.052]		
$\pi^{P2} - \pi^*_{-1}$		**0.334***** [0.079]	
$\pi^{P3} - \pi^*_{-1}$			**0.284***** [0.058]
Observations	127	127	127
R^2	0.223	0.143	0.185

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 years, the length of which corresponds to the current targeting period.

Lastly, the analyses are based on the causal relation from past inflation rates to inflation targets. That is, inflation rates in the previous years are included on the right side and inflation targets are included on the left side of Equation (1). However, a reverse causal relation between inflation targets and inflation rates may exist, which is originally intended by a successful inflation-targeting regime. To control for potential reverse causation, we additionally consider the following equation:

$$\pi_{it} - \pi^P_{it} = \gamma_0 + \gamma_1(\pi^*_{it} - \pi^P_{it}) + \varepsilon_{it}, \qquad (2)$$

where π_{it} indicates the average inflation rate in the current period. This equation allows for the possibility that changes in actual inflation from the previous period depend on the deviation of the current inflation target from the previous inflation rate because the actual inflation rate may increase (or decrease) when the central banks increase (or decrease) the target.

The system of Equations (1) and (2) is estimated using the three-stage least squares (3SLS) method. Table 3 reports the results. System estimation does not imply any relevant differences in the results. The estimates of coefficient $\alpha_1$are still significantly different from zero and positive. The size of the point estimates is from 0.13 to 0.21, which is quite similar to the baseline results.

Table 4: System Estimation Results

	Equation (1)				**Equation (2)**		
	$\Delta\pi^*$				$\Delta\,\pi$		
$const$	–1.271 [1.116]	–1.197 [1.120]	0.186 [1.279]	$const$	–1.642 [1.332]	1.442 [1.198]	–1.706 [1.323]
$\pi^{P1}-\pi^*_{-1}$	**0.187***** [0.065]			$\pi^*-\pi^{P1}$	0.873*** [0.058]		
$\pi^{P2}-\pi^*_{-1}$		**0.132**** [0.052]		$\pi^*-\pi^{P2}$		1.038*** [0.051]	
$\pi^{P3}-\pi^*_{-1}$			**0.205***** [0.068]	$\pi^*-\pi^{P3}$			0.843*** [0.060]
Observations	161	161	161	Observations	161	161	161
R^2	0.273	0.266	0.277	R^2	0.593	0.729	0.584

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 years, the length of which corresponds to the current targeting period.

2.3. Central Bank Performance

In this study, we find that central banks tend to adjust their inflation targets to correct for the misses from the target. Then, an important question is why such a tendency exists. [3] In the introduction, we discuss the possibility that central banks try to narrow the gap between the actual inflation rate and the inflation target by setting a new inflation target to maintain its reputation under the pressure of hitting target ranges. In this case, we may observe such tendencies intensifying among central banks that have weak reputations or performances. In other words, when central banks have a relatively weak inflation targeting performance, they are likely to have an incentive to improve their reputation by changing the inflation target, thereby reducing the deviation of realized inflation rates from the inflation target. In this subsection, we examine the relationship between central bank performance and the degree of tendencies of central banks to adjusting their inflation target to correct their misses.

We use this central bank performance indicator in the analysis:

$$performance\ indicator = (\pi_t - \pi_t^*)^2, \quad (3)$$

where π_t and π_t^* are the actual inflation rate and inflation target, respectively. In Equation (3), 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 your pronouncements are believed" (Blinder, 1998). Recently, Bordo and Siklos (2014, 2015a, 2015b) have measured 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 (3). Bordo and Siklos (2014, 2015a, 2015b) also estimate the "implied inflation objective" from the monetary policy rule, such as the Taylor Rule, as a proxy for π_t^*. The current study uses the exact inflation target data that central banks have announced because we only consider cases of countries that have announced their inflation targets.

[3] With respect to the upward adjustment of the inflation target in 2005 discussed in the introduction of this paper, the Bank of Indonesia (2007) claimed that the assumptions during 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 was criticized for making actual decisions that did not reflect the commitment to an inflation targeting framework (McLeod [2008]).

We compute the average of the performance indicator after the adoption of the inflation targeting regime of each country using their monthly inflation data. We then classify 19 countries into two groups based on the average values of their performance indicators. 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 on the indicator values and the classification of countries is shown in Table A2 of the Appendix.

Table 5 presents the estimation results of each group for Equation (1). The difference between the two groups is clear. In the high-performance group, the estimated coefficients are not significantly positive in any case. However, the coefficient estimates are positive and significant in all cases in the low-performance group. Moreover, the size of estimates in the latter group is even larger than the baseline estimation results shown in Table 1. This result suggests that central banks in the low-performance group are more responsive to misses when they set new inflation targets.

In addition, 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 on the average inflation rates and the classification of countries is also shown in Table A2 of the Appendix. With this grouping method, we find results similar to those countries from that are divided based on the performance indicator in Equation (3). The estimation results are reported in Table 6. The estimated coefficients are positive and significant only in the high inflation group.

We also would like to note that the experiment in this section is not subject to the potential reverse causation problem. A large estimated coefficient in the regression does not necessarily imply that there is a large discrepancy between actual and target inflation rates. Rather, it means that the target adjusts more (relative to the deviation of actual rate from the target in the previous period) in response to a deviation of actual rate from the target in the previous period. In other words, bad performance (a large discrepancy between actual and target inflation rates) may lead to a low level of the credibility measure, but more target adjustments (relative to the deviation of actual rate from the

target) in response to a deviation of actual rate does not necessarily lead to a low level of the credibility measure.

Table 5: Role of Targeting Performance

	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 of the previous years, the length of which corresponds to the current targeting period.

Table 6: Low Inflation versus High Inflation Countries

	Countries with Low Inflation			**Countries with High Inflation**		
	$\Delta\pi^*$			$\Delta\pi^*$		
$const$	–0.661*** [0.171]	–0.558*** [0.173]	–0.672*** [0.172]	–1.742*** [0.355]	–1.855*** [0.354]	–1.790*** [0.363]
$\pi^{P1} - \pi^*_{-1}$	**0.036** [0.088]			**0.242**** [0.097]		
$\pi^{P2} - \pi^*_{-1}$		**–0.137**** [0.067]			**0.237***** [0.078]	
$\pi^{P3} - \pi^*_{-1}$			**0.056** [0.096]			**0.254**** [0.100]
Observations	73	73	73	88	88	88
R^2	0.003	0.064	0.006	0.074	0.106	0.076

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 years, the length of which corresponds to the current targeting period.

3. Analytical Illustration

3.1. Simple New Keynesian Model

This section illustrates the consequences of the inflation-targeting central bank's behavior of adjusting targets to meet the target. We consider the standard New Keynesian model that was frequently used in past studies, such as Clarida, Gali, and Gertler (1999). The linearized form of the equation system is as follows:

$$\beta E_t \pi_{t+1} = \pi_t - \kappa x_t, \quad (4)$$

$$E_t x_{t+1} = x_t + \frac{1}{\sigma}(i_t - E_t \pi_{t+1}) - u_t, \quad (5)$$

$$i_t = \delta(\pi_t - \pi_t^*), \quad (6)$$

where x_t, i_t, π_t, and π_t^* are output gap, interest rate, inflation rate, and inflation target (all in percentage deviations from the steady state), respectively. $u_t \equiv \left(\frac{1+\eta}{\sigma+\eta}\right) E_t(z_{t+1} - z_t)$, and z_t is a technology shock. $\kappa \equiv \frac{(\sigma+\eta)(1-\varpi)(1-\beta\varpi)}{\varpi}$, and β, σ, δ, η, and ϖ are discount factor, degree of relative risk aversion, a monetary policy reaction parameter, a preference parameter on labor ($\frac{1}{\eta}$ is a Frisch elasticity of labor supply), and the probability of a firm being allowed to change the price (in Calvo [1983] pricing). Equation (4) is the new Keynesian Phillips curve and Equation (5) is the dynamic IS curve. Equation (6) shows a simple monetary policy rule in which the monetary authority is assumed to set the interest rate in response to the deviation of the current inflation rate from the inflation target. We assume that $\delta \geq 0$.

When the inflation target is constant, a unique equilibrium exists when $\delta > 1$, as discussed in past studies, such as Clarida, Gali, and Gertler (1999). However, when $\delta < 1$, 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.

We now consider the case in which the central bank adjusts its inflation target to meet the target when the actual inflation rate deviates from the target in the previous period.

$$\pi_t^* - \pi_{t-1}^* = \phi(\pi_{t-1} - \pi_{t-1}^*), \tag{7}$$

where we assume that $0 < \phi \leq 1$.[4]

In this case, the system of equations (Equations [4], [5], [6], and [7]) are reduced to the following:

$$\begin{bmatrix} E_t x_{t+1} \\ E_t \pi_{t+1} \\ \pi_{t+1}^* \end{bmatrix} = A \begin{bmatrix} x_t \\ \pi_t \\ \pi_t^* \end{bmatrix} + \begin{bmatrix} -u_t + \frac{1}{\sigma} v_t \\ 0 \\ 0 \end{bmatrix} \tag{8}$$

where $A = \begin{bmatrix} 1 + \frac{\kappa}{\beta\sigma} & \frac{\delta}{\sigma} - \frac{1}{\beta\sigma} & -\frac{\delta}{\sigma} \\ -\frac{\kappa}{\beta} & \frac{1}{\beta} & 0 \\ 0 & \phi & 1 - \phi \end{bmatrix}$.

The characteristic equation of the matrix A is

$$\lambda^3 + A_2\lambda^2 + A_1\lambda + A_0 = 0, \tag{9}$$

where $A_0 = \frac{\phi}{\beta} - \frac{1}{\beta} - \frac{\delta\kappa}{\beta\sigma}$, $A_1 = \frac{2}{\beta} + 1 + \frac{\kappa}{\beta\sigma} - \frac{\phi}{\beta} - \phi - \frac{\phi\kappa}{\beta\sigma} + \frac{\delta\kappa}{\beta\sigma}$, and $A_2 = \phi - \frac{1}{\beta} - 2 - \frac{\kappa}{\beta\sigma}$.

For a rational expectation equilibrium to be determinate, Equation (9) should have one root inside the unit circle and two roots outside the unit circle. Woodford (2003) showed that rational expectation equilibrium is determinate if and only if

Either (Case I)

[4] The result is the same when we allow a small deviation from Equation (7) to avoid a potential unit root problem in the system, that is, $\pi_t^* - (1-\tau)\pi_{t-1}^* = \phi_0 + \phi(\pi_{t-1} - \pi_{t-1}^*)$, where τ is a very small positive number.

$1 + A_0 + A_1 + A_2 < 0$ and $-1 + A_0 - A_1 + A_2 > 0$

or (Case II)

$1 + A_0 + A_1 + A_2 > 0$, $-1 + A_0 - A_1 + A_2 < 0$, and $A_0^2 - A_0 A_2 + A_1 - 1 > 0$

or (Case III).

$1 + A_0 + A_1 + A_2 > 0$, $-1 + A_0 - A_1 + A_2 < 0$, $A_0^2 - A_0 A_2 + A_1 - 1 < 0$, and $|A_2| > 3$

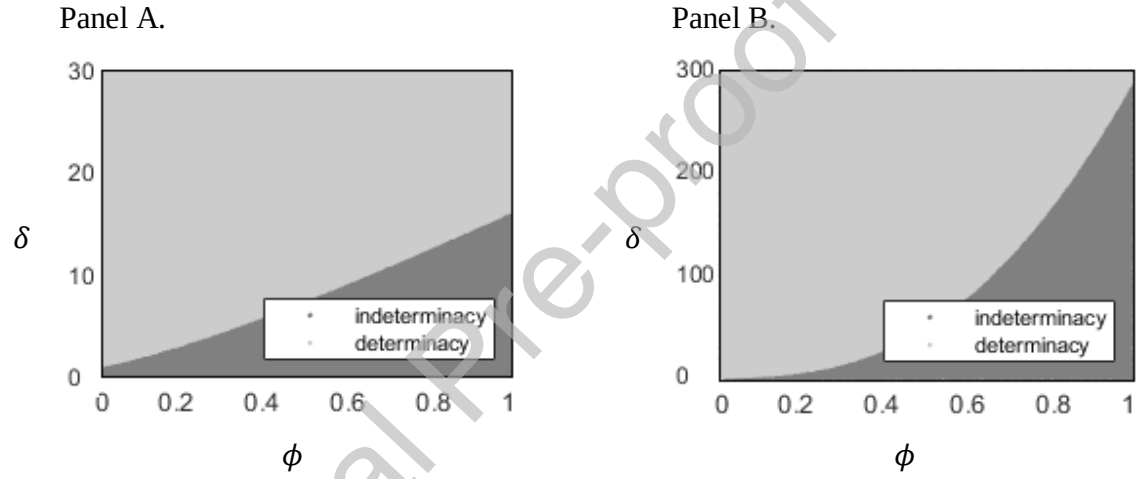
For Equation (9), $1 + A_0 + A_1 + A_2 = -\frac{\phi\kappa}{\beta\sigma} < 0$ and $-1 + A_0 - A_1 + A_2 = -\frac{(\kappa + 2\sigma + 2\beta\sigma)(2-\phi) + 2\delta\kappa}{\beta\sigma} < 0$. Therefore, none of the Cases I, II, and III hold, and equilibrium is indeterminate. Equation (7) suggests that the central bank tries to reduce the gap between the actual inflation rate and the target by adjusting the inflation target for the next period proportionately to the current gap, provided that the actual rate does not meet the target. In this case, inflation expectations and the actual inflation rate do not need to be stabilized because the target adjustments would close the deviation of the actual inflation rate from the target for any level of inflation rate. Interestingly, the equilibrium is indeterminate regardless of the size of the dependence of adjustments in target on past deviation from the target (ϕ) and the size of the inflation dependence in monetary policy rule (δ).

3.2. Extended Models

We further explore the consequences of the inflation-targeting central bank's behavior of adjusting targets to meet the target in more realistic models. First, we consider the model from Smets and Wouters (2007) that better fits the data with backward-looking components and more frictions. Second, we consider Ascari and Sbordone's (2014) model, in which positive trend inflation rate is allowed. We utilize the parameter values used in the baseline model of each study. For Ascari and Sbordone's (2014) model, a 4% trend inflation rate is used.

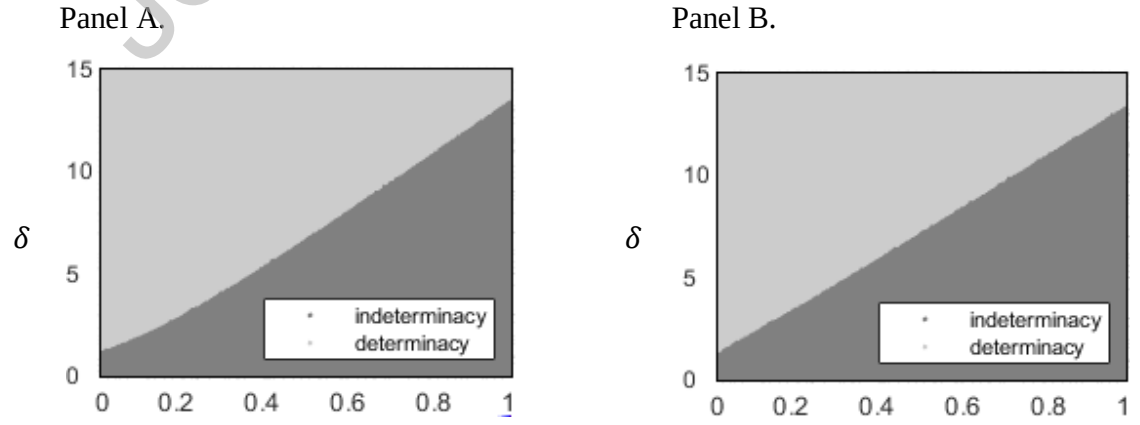
Figures 1 and 2 show the indeterminacy region in the models of Smets and Wouters (2007) and Ascari and Sbordone (2014), respectively. For both Figures 1 and 2, Panel A represents the result when output gap (and interest rate smoothing for Smets and Wouters) is allowed in the monetary policy rule while Panel B represents the result when it is not. In each panel, the y-axis shows the value of δ while the x-axis shows the value of ϕ. The darker area represents the indeterminacy region while the lighter area represents the determinacy region.

Figure 1: Indeterminacy Region using Smets and Wouters's (2007) Model



Note: Panel A represents the result when output gap and interest rate smoothing components are included in the monetary policy rule while Panel B represents the result when they are not. The darker area represents the indeterminacy region while the lighter area represents the determinacy region.

Figure 2: Indeterminacy Region using Ascari and Sbordone's (2014) Model



ϕ ϕ

Note: Panel A represents the result when output gap is included in the monetary policy rule while Panel B represents the result when it is not. The darker area represents the indeterminacy region while the lighter area represents the determinacy region.

The results show that in all cases, as target adjustments become increasingly dependent on past deviations from the target (i.e., as the size of δ increases), a stronger response to the inflation rate in monetary policy rule (ϕ) is required for an equilibrium determinacy. That is, it becomes increasingly difficult for central banks to achieve equilibrium determinacy as they adjust inflation targets more aggressively in response to past deviations of inflation rates from the target. If the central bank tries to reduce the gap between the actual inflation rate and the target by adjusting the inflation target more aggressively, other things being equal, inflation expectation and the actual inflation rate would be less stabilized because the target adjustments will force the gap between the actual inflation rate and the target to close. This may imply that the central bank requires a forcible adjustment of the interest rate to the inflation rate to stabilize inflation expectation and the actual inflation rate.

4. Conclusion

This study empirically investigates whether central banks adjust their inflation targets to meet their targets in 19 inflation-targeting countries. The empirical results show that changes in the inflation target of many central banks significantly and positively respond to the deviation of past inflation rate from the target. The results of this study support that inflation-targeting central banks respond to misses on their inflation targets by adjusting the inflation target to meet the target. We also show that such a relationship is strongest in central banks with low credibility or weak performance, suggesting that the relationship 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 show that such behavior can lead to equilibrium indeterminacy in the standard New Keynesian model. Further, such behavior renders achieving equilibrium determinacy harder for central banks even in more realistic models.

Future studies are necessary.[5] First, further investigation on how inflation-targeting central banks set their inflation targets is important. Second, thorough general analysis regarding the consequences of various inflation target-setting behavior of central banks is worthwhile.

[5] See Kim and Yim (2016) for analysis in this direction.

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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%		16.0%	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%			2.0~4.0%		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%					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%	8.0±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%	3.0±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%							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%		5.5±1.0% 5.0±1.0%	3.5±1.0% 3.5±1.0%	7.5% 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%			3.0±1.0%	5.0±1.0% 4.5±1.0%	3.0±1.0% 3.0±1.0%	5.5%	9.0±2.0%
2012		0.5~3.0%	4.0±1.0%	4.5±1.0%				3.0±1.0%	4.5±2.0%		2.0±1.0%						8.5±2.0%
2013				4.5±1.0%			2.0±1.0%		4.5±2.0%	3.0±1.0%				4.0±1.0%	2.5±1.0%	5.0%	9.0±2.0%
2014	2.5~3.5%			4.5±1.0%					4.5±2.0%								9.5±2.0%
2015			3.0±1.0%	4.0±1.0%					4.5±2.0%								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 when inflation targeting became official.
2. The underlined numbers indicate core inflation.
3. Israel shifted to long-term inflation targeting in August 2000. Since 2003, the 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 a medium-term target horizon since 2003.

7. From 2013, the phase of a flat, multi-annual, inflation-target intermediate stage meant ensuring 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%		1.0 ~ 3.0%												
1999															
2000															
2001	0.0 ~ 3.0%		1.0 ~ 3.0%												
2002															
2003															
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										N.A.					
2009			1.0 ~ 3.0%			3.0 ~ 6.0%	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 when inflation targeting became official.
2. In the UK, the inflation target index was changed from RPIX into CPI in 2004.
Sources: Central Banks and others

Table A2: 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 of inflation groups, respectively.