Non-Linear Incentives and Intertemporal Consistency in Inflation Targeting Regimes*

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Abstract

This paper examines the institutional setup of an inflation targeting system where the Central Bank determines the target. Building on Walsh (1995), we show that, unlike the traditional solution, the incentive contract that induces an intertemporally consistent solution is not linear and may depend on the level of inflation or the deviation from the announced target to punish the Central Bank.

Keywords: Dynamic Inconsistency; Inflation Target; Monetary Policy.

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1 Introduction

Central Banks generally have the primary objective of keeping inflation close to the target. However, they face the challenge that the effectiveness of monetary policy may be limited by the time preferences of policymakers. Conducting monetary policy based on the political's preferences, however, can lead to intertemporal inconsistency, making policy discretionary and weakening the commitment to the inflation-targeting regime (Alesina and Stella, 2010; Aklin and Kern, 2021).[1] Intertemporal consistency in inflation targeting is important to maintain the Central Bank credibility and avoid an inflation bias, and Central Bank independence could be a solution to the time inconsistency problem (Garriga and Rodriguez, 2020; Aklin and Kern, 2021).

The challenge of dynamic inconsistency in monetary policy has been the subject of intense debates, especially regarding the creation of incentives for more consistent policies. Since then, various models have been devised in an attempt to solve the problem of dynamic inconsistency in monetary policy, among which stands out the contract-based approach proposed by Walsh (1995). In his model, he developed an optimal contract based on a principal-agent framework. Specifically, the government sets a linear transfer for the Central Bank that includes a penalty for inflation. This approach aims to eliminate the incentive for the Central Bank to deviate from the optimal policy, preventing the creation of surprise inflation.

We developed a model building on Walsh (1995) to study how an independent Central Bank may respond to linear and non-linear incentives. We allow the monetary authority to be completely independent in defining the inflation level and target inflation as in Araujo et al. (2016).[2] Within this theoretical framework, we show that the standard linear contract does not induce commitment. Additionally, we show that there are two optimal non-linear incentive schemes, one that targets the inflation level and the other that aims the deviation from the announced inflation target, which induces an equilibrium where the announcement of the inflation target is credible, as such, it solves the credibility problem put by Cukierman and Liviatan (1991), although it is not resilient to parameter uncertainty problems like that of

[1] Binder (2021) provides empirical evidence that political pressures on Central Banks are associated with higher inflation and inflation persistence.

[2] Australia, New Zealand, Sweden, and Brazil are examples of countries whose Central Bank is independent in choosing the inflation target. There are empirical evidence that shows that the independence of the Central Bank is associated with lower levels of inflation (Garriga and Rodriguez, 2020).

Vickers (1986).

Araujo et al. (2016) analyze the limitations of coordination of expectations in inflation targeting regimes, showing that low targets, although desirable, are difficult to sustain due to the risk of multiple equilibria and the temptation of the Central Bank to fail to comply with them. In models with imperfect information, greater imprecision in public information may, paradoxically, improve coordination and facilitate compliance with targets, as it reduces speculation. Excessive transparency, on the other hand, increases the likelihood of distrust and credibility crises. Thus, they suggest that higher targets and less transparency may be more effective for Central Banks with less commitment capacity.

We depart from Araujo et al. (2016) in two significant ways. Firstly, unlike Araujo et al. (2016), where the Central Bank possesses private information that influences the expectations of the private sector, we assume that the Central Bank and the private sector have symmetric information. This change eliminates the information asymmetry channel through which the announced target would affect private sector expectations in Araujo et al. (2016). In our model, the private sector is focused on the inflation implemented by the Central Bank. The inflation target works as an additional communication mechanism for the Central Bank. Secondly, we introduce a model of continuous punishments for deviations from the target, in contrast to the constant punishment for any deviation used by Araujo et al. (2016). Continuous punishments reflect the concept that larger deviations lead to increasingly greater losses, as smaller deviations are unlikely to incur losses of the same magnitude as larger ones. Our contribution lies in analyzing these two differences, providing new insights into the behavior and policy implications of the Central Bank's target-setting.

Chortareas and Miller (2004) analyze linear contracts in a common agency framework, where the central banker can formally contract with the government and informally with a private interest group. They find that when monetary policy is delegated through inflation contracts and the interest group offers an output contract, the incentive scheme from the interest group replicates the discretionary outcome of Barro and Gordon (1983) models. Campoy and Negrete (2008) challenge this by considering the central bank's participation constraint, leading to three key results: the government should set a zero penalty rate to eliminate inflationary bias; an inflation bias can arise if both principals offer inflation contracts, with a non-zero optimal penalty rate; and indeterminacy in fixed sums paid by principals does not affect equilibrium macroeconomic variables like output and inflation.

Ciccarone and Marchetti (2012) emphasizes the importance of linear incentive contracts in monetary policy, highlighting their superiority over other approaches, such as the legislative solution and the reputation solution. They also highlight the degree of uncertainty regarding the central bank's conservatism, production target and its ability to respond to incentives can affect the effectiveness of linear contracts in eliminating inflationary bias and stabilizing the economy. Dai and André (2022) investigate whether the design of linear inflation contracts to reduce inflation bias in the Barro-Gordon model applies to the New Keynesian model. They find that while linear inflation contracts do help reduce inflation undershooting and partially eliminate the inflation bias in the New Keynesian model, the optimal designs differ significantly from those in the Barro-Gordon model.

We show that the linear transfer function fails to constrain the central bank's policy choices, as it allows the authority to manipulate the inflation target without incurring a proportional penalty. As an alternative, we suggest a non-linear transfer function that penalizes deviations of inflation from the target, instead of focusing only on the inflation level. This deviation-based transfer function has two main advantages: (1) it implements an optimal inflation policy by better aligning economic agents' expectations with the inflation target, and (2) it avoids unnecessary transfers in equilibrium, resulting in higher welfare for the Central Bank and the private sector.

The structure of the paper is as follows, in Section 2 we define the model and solve the traditional transfer function of the Walsh Contract. In Section 3 we derive the ideal transfers and compare their welfare effects. Finally, in Section 4 we present final remarks.

2 Structuring the Game

The policy game is based on Barro and Gordon (1983) to fit an inflation targeting regime and is very similar to Cukierman (2000) inflation announcement game. The game takes place over three turns with the following structure:

1. The monetary authority announces an inflation target ($\bar{\pi}$);

2. The private sectors set their expectations given the target (π^e);

3. The monetary authority chooses the inflation policy ($\hat{\pi}$).

After that inflation realizes and payoffs are paid.

In our economy, the inflation level is given by $\pi = \hat{\pi} + \varepsilon$, where $\hat{\pi}$ is a choice of the monetary authority and ε is a mean-zero random variable with variance ${\sigma_\varepsilon}^2$. The shock ε represents potential measurement errors, instrument velocity shock, or a control error added to the chosen instrument level to give the period's inflation. The monetary authority's utility is given by the standard quadratic loss function with a stochastic component and a transfer function and can be written as

$$U_{CB} = -\frac{a}{2}(\pi - \pi^*)^2 - \frac{b}{2}(y - \gamma\bar{y})^2 + T, \tag{1}$$

where π is the inflation level, π^* is the monetary authority's preferred level of inflation, y is the realized output, $\bar{y}$ is the potential output, and γ is a positive parameter that measures the cost associated with deviations of the realized output from the potential output. T is a linear transfer function of the form $T = c - d(\pi - \bar{\pi})$, where c represents a fixed transfer that does not depend on inflation or output, d is a coefficient that penalizes deviations of inflation from the target, and $\bar{\pi}$ is the inflation target.

The trade-off faced by the Central Bank is given by an Expectation-Augmented Stochastic Phillip's Curve of the form

$$y = \bar{y} + \alpha(\pi - \pi^e) + \phi, \tag{2}$$

where α is a positive parameter that reflects the effectiveness of surprise inflation in stimulating the economy, π^e is the inflation expectation of the private sector and ϕ is a zero-mean random variable with variance σ_ϕ^2 that represents exogenous output shocks.

Note that when $\gamma = 1$, the Central Bank aims to stabilize the output at its natural level, ensuring that realized output equals potential output. On the other hand, when $\gamma > 1$ the trade-off happens, because the Central Bank prefers the economy to operate above the potential output, which leads to inflation surprises, as described by the Phillips Curve.

Finally, the utility of the private sector is represented as a quadratic function:

$$U = -(\pi - \pi^e)^2. \tag{3}$$

This simple functional form reflects well the idea that private agents are averse to deviations from inflation, preferring to anticipate it correctly.[3]

By hypothesis, all utility parameters are *common knowledge* and there is perfect information, so the solution by backward induction is straightforward and is summarised by the following propositions:

Proposition 1. *If the transfer function is $T = c - d(\pi - \bar{\pi})$, there is no equilibrium.*

Proof. The Central Bank is faced with the following problem

$$\underset{\hat{\pi}}{\text{Max}}\ \mathbb{E}\left[-\frac{a}{2}\Big(\hat{\pi}+\varepsilon-\pi^*\Big)^2 - \frac{b}{2}\Big((1-\gamma)\bar{y}+\alpha(\hat{\pi}+\varepsilon-\pi^e)+\phi\Big)^2 + T\right]. \tag{4}$$

With the transfer function $T = c - d(\pi - \bar{\pi})$ the Central Bank's Monetary Policy problem becomes

$$\underset{\hat{\pi}}{\text{Max}}\ \mathbb{E}\left[-\frac{a}{2}\Big(\hat{\pi}+\varepsilon-\pi^*\Big)^2 - \frac{b}{2}\Big((1-\gamma)\bar{y}+\alpha(\hat{\pi}+\varepsilon-\pi^e)+\phi\Big)^2 + c - d(\pi-\bar{\pi})\right], \tag{5}$$

resulting in

$$\hat{\pi} = \frac{a\pi^* + b\alpha(\gamma-1)\bar{y} - d}{a}$$

To determine the optimal inflation target, note that the only term dependent on the inflation target is the transfer function itself. Thus, the optimization condition for the Central Bank can be expressed as:

$$\frac{\partial U_{CB}}{\partial \bar{\pi}} = \frac{\partial T}{\partial \bar{\pi}} = d.$$

If $d > 0$, this implies that the higher the inflation target, the greater the utility of the Central Bank. In this case, no equilibrium can exist, as the Central Bank would always have an incentive to increase the target, leading to an inconsistent dynamic.

[3]Some papers in traditional literature use the quadratic loss function, for example Barro and Gordon (1983), Canzoneri (1985) and Walsh (1995).

On the other hand, if $d < 0$, the problem becomes finding a value of d that resolves the time inconsistency. The value of d in this case is given by:

$$d = b\alpha(\gamma - 1)\bar{y},$$

which, however, is a positive number. This implies that there is no sustainable equilibrium with $d < 0$ capable of eliminating the inflation bias.

$\square$

Proposition 2. *There is no additively separable transfer function such that the inflation policy is equal to the inflation target, that is, $\hat{\pi} = \bar{\pi}$.*

Proof. Let $T(\hat{\pi}, \bar{\pi})$ be a function such that it can be represented as $T(\hat{\pi}, \bar{\pi}) = f(\hat{\pi}) + g(\bar{\pi})$. The Central Bank's inflation setting problem can be written as

$$\underset{\hat{\pi}}{\text{Max}}\ \mathbb{E}\left[-\frac{a}{2}\left(\hat{\pi} + \varepsilon - \pi^*\right)^2 - \frac{b}{2}\left((1-\gamma)\bar{y} + \alpha\left(\hat{\pi} + \varepsilon - \pi^e\right) + \phi\right)^2 + f(\hat{\pi}) + g(\bar{\pi}) \right]. \tag{6}$$

which yields the following first-order condition

$$\hat{\pi} = \frac{a\pi^* + b\alpha^2\pi^e - b\alpha(1-\gamma)\bar{y} + f'(\hat{\pi})}{a + b\alpha^2}.$$

As we want a $f(\hat{\pi})$ such that our FOC is $\hat{\pi} = \bar{\pi}$, we can rewrite as

$$f'(\hat{\pi}) = (a + b\alpha^2)\bar{\pi} - a\pi^* - b\alpha^2\pi^e + b\alpha(1-\gamma)\bar{y}, \tag{7}$$

which is a contradiction since, if T is an additively separable function, $\frac{\partial T}{\partial \hat{\pi}} = f'(\hat{\pi})$ cannot have $\bar{\pi}$ as an argument. $\square$

Usually the additive separability hypothesis is used to simplify the decision making problem by eliminating the cross-partial derivatives, but in our case, it's precisely those that give any credibility to the announcements of the Central Bank and makes them accountable on their policy choice.

3 Devising the Optimal Commitment Technology

The question we pose in this section is whether there exists a transfer function similar to that of Walsh (1995), such that the announcements of the monetary authority become a costly signal rather than cheap talk, as in Cukierman and Liviatan (1991), forcing central bankers to adopt a policy consistent over time. Our result is the following proposition:

Proposition 3. *The transfer functions $T_1 = (a\pi^* - a\bar{\pi} - b\alpha(1-\gamma)\bar{y})\pi$ and $T_2 = (a\pi^* - a\bar{\pi} - b\alpha(1-\gamma)\bar{y})(\pi - \bar{\pi})$ induce that the inflation target is equal to the inflation level, that is, $\bar{\pi} = \pi$.*

Proof. The Central Bank's problem is stated Equation (4), and the derivative with respect to $\hat{\pi}$ is

$$-a\hat{\pi} + a\pi^* - b\alpha^2\hat{\pi} + b\alpha^2\pi^e - b\alpha(1-\gamma)\bar{y} + \frac{\partial T}{\partial \hat{\pi}} = 0.$$

To find the optimal transfer function we follow a similar process to Proposition 2, that is, as we want to find T such that $\mathbb{E}(\pi) = \bar{\pi}$, our first order condition must result in $\hat{\pi} = \bar{\pi}$ at the optimum (the Consistency Constraint), and thus we can rewrite the FOC to solve for $\frac{\partial T}{\partial \hat{\pi}}$ as

$$\frac{\partial T}{\partial \hat{\pi}} = -a\pi^* + a\bar{\pi} - b\alpha^2\pi^e + b\alpha^2\bar{\pi} + b\alpha(1-\gamma)\bar{y}.$$

Note that if there exists a function that satisfies this property and this function is common knowledge (i.e the Central Bank's contract is public), rational expectations guarantees that the people's best response is $\pi^e = \bar{\pi}$, thus the FOC simplifies to

$$\frac{\partial T}{\partial \hat{\pi}} = a\bar{\pi} - a\pi^* + b\alpha(1-\gamma)\bar{y}. \tag{8}$$

Integrating it with respect to the inflation level or the inflation deviation from the target yields $T_1 = (a\bar{\pi} - a\pi^* + b\alpha(1-\gamma)\bar{y})\pi$ and $T_2 = (a\bar{\pi} - a\pi^* + b\alpha(1-\gamma)\bar{y})(\pi - \bar{\pi})$.[4] □

Like in Walsh (1995), the parameters of both transfer functions are the same, changing only in what outcome is monitored, the inflation level, or the deviation from the target, and yet they show different properties and equilibria, which are demonstrated in the following proposition.

[4] We assume that the Central Bank cannot refuse the contract so we omit the constant.

Proposition 4. *If* $T_1 = (a\bar{\pi} - a\pi^* + b\alpha(1-\gamma)\bar{y})\pi$, *at equilibrium* $\pi = \pi^e = \bar{\pi} = \frac{b\alpha}{a}(\gamma - 1)\bar{y}$ *and* $T_1 = -b\alpha(\gamma-1)\bar{y}\pi^*$*; and if* $T_2 = (a\bar{\pi} - a\pi^* + b\alpha(1-\gamma)\bar{y})(\pi - \bar{\pi})$, *at equilibrium* $\hat{\pi} = \pi^e = \bar{\pi} = \pi^*$ *and* $T_2 = 0$.

Proof. The choice of the inflation level was defined in Proposition 3, where $\bar{\pi} = \hat{\pi} = \pi^e$. Thus, we need to solve the Central Bank's inflation targeting problem, which is analogous to the one described in Equation (4), considering both transfer functions. The key difference is that, in this case, we aim to determine the announced inflation target, $\bar{\pi}$.

1. For $T_1 = (a\bar{\pi} - a\pi^* + b\alpha(1-\gamma)\bar{y})\pi$, we can write the Central Bank inflation target setting problem as

$$\underset{\bar{\pi}}{\text{Max}}\ \mathbb{E}\left[-\frac{a}{2}\Big(\bar{\pi}+\varepsilon-\pi^*\Big)^2 - \frac{b}{2}\Big((1-\gamma)\bar{y}+\alpha\varepsilon+\phi\Big)^2 + (a\bar{\pi}-a\pi^*+b\alpha(1-\gamma)\bar{y})(\bar{\pi}+\varepsilon)\right], \quad (9)$$

that yields

$$\bar{\pi} = \frac{b\alpha}{a}(\gamma - 1)\bar{y}.$$

Substituting the optimal inflation target in the transfer function and taking expectation gives us

$$\mathbb{E}(T_1) = -b\alpha(\gamma - 1)\bar{y}\pi^* < 0, \quad \text{if } \pi^* > 0. \quad (10)$$

2. Similarly, for $T_2 = (a\bar{\pi} - a\pi^* + b\alpha(1-\gamma)\bar{y})(\pi - \bar{\pi})$ we have

$$\underset{\bar{\pi}}{\text{Max}}\ \mathbb{E}\left[-\frac{a}{2}\Big(\bar{\pi}+\varepsilon-\pi^*\Big)^2 - \frac{b}{2}\Big((1-\gamma)\bar{y}+\alpha\varepsilon+\phi\Big)^2 + (a\bar{\pi}-a\pi^*+b\alpha(1-\gamma)\bar{y})\varepsilon\right]. \quad (11)$$

The first-order condition gives $\bar{\pi} = \pi^*$. By substituting this expression into the transfer function and taking the expectation we obtain $\mathbb{E}(T_2) = 0$.

□

From Proposition 4, we see that punishing deviations from the target has two desirable properties, it implements the optimal inflation policy and there is no transfer on equilibrium.

Corollary 1. *Imperfect control of inflation and supply shocks don't change the Central Bank's decision, on average, if the the probability distribution of both are common knowledge.*

Proof. If we assume that $\varepsilon = \phi = 0$, and solve the problem defined in Proposition 4 we will obtain the same result, that is, $\bar{\pi} = \pi^*$ and $\bar{\pi} = \frac{b\alpha}{a}(\gamma - 1)\bar{y}$. $\square$

Corollary 2. *Punishing the deviation from inflation target generates a higher welfare.*

Proof. Consider the transfer functions $T_1 = (a\bar{\pi} - a\pi^* + b\alpha(1-\gamma)\bar{y})\pi$ and $T_2 = (a\bar{\pi} - a\pi^* + b\alpha(1-\gamma)\bar{y})(\pi - \bar{\pi})$. By substituting both in the central bank's utility function and taking the expectation we obtain

$$\mathbb{E}(U_{CB}^1) = -\frac{1}{2}\left(\frac{b}{a}(1-\gamma)^2\bar{y}^2(a + b\alpha^2) + (a + b\alpha^2)\sigma_\varepsilon^2 + b\sigma_\phi^2 + a\pi^{*2}\right), \tag{12}$$

and

$$\mathbb{E}(U_{CB}^2) = -\frac{1}{2}\Big((a + b\alpha^2)\sigma_\varepsilon^2 + b(1-\gamma)^2\bar{y}^2 + b\sigma_\phi^2\Big), \tag{13}$$

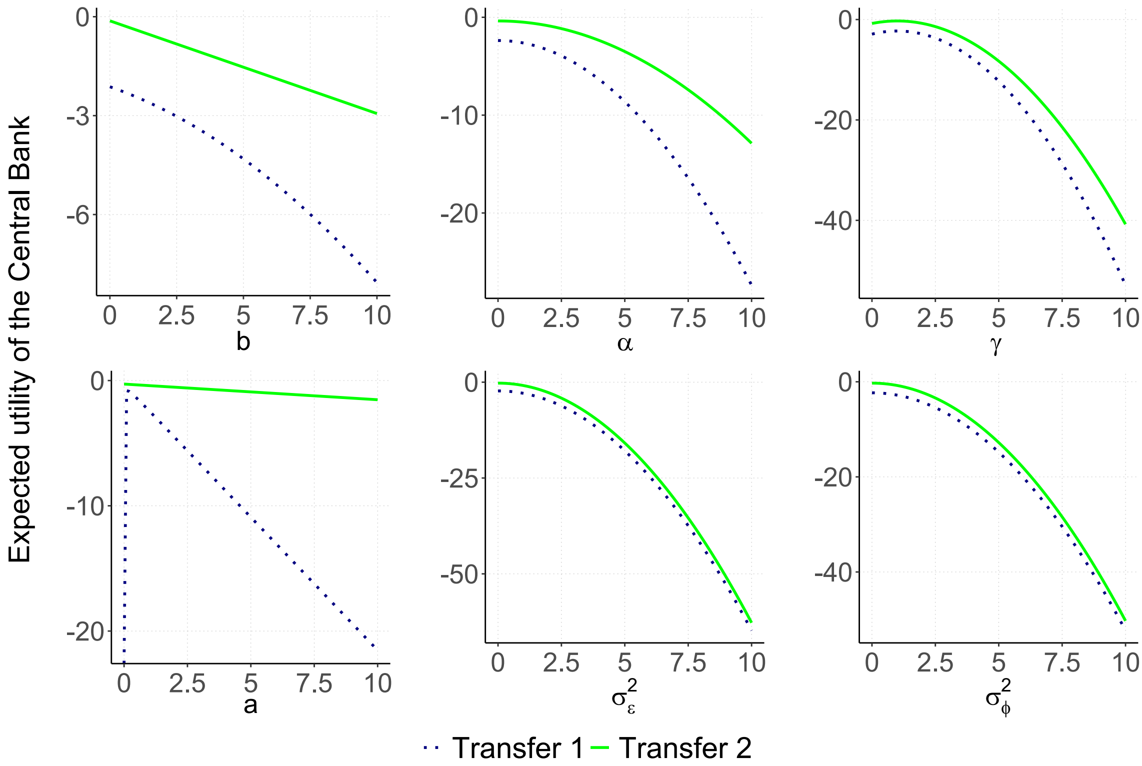
respectively. As the private sector cares only about the squared surprise inflation and both transfer functions yield $\hat{\pi} = \pi^e$, their utility is simply σ_ε^2, so the difference in welfare is given only by the utility of the monetary authority. By inspection of Equations (12) and (13) we can see that $T_2 = (a\bar{\pi} - a\pi^* + b\alpha(1-\gamma)\bar{y})(\pi - \bar{\pi})$ has a higher utility for any central banker. The intuition behind the result is that punishing the Central Bank based on inflation levels incentivizes an inflation level different then his prefered policy π^*, making him worse off without increasing the utility of the private sector. $\square$

We conducted a numerical simulation by varying six parameters (b, α, γ, a, σ_ϵ^2, and σ_ϕ^2) within the range of zero to ten, calculating the expected utility of the Central Bank for each of the transfer functions. Figure 1 illustrates the results. The green line represents the expected utility under T_2, while the dotted blue line corresponds to the expected utility under T_1.

It is observed that as b (the weight given to output deviations) increases, the expected utility decreases for both mechanisms, but T_2 consistently outperforms T_1. This same pattern is observed for a (the weight given to inflation deviations) and γ (the Central Bank's preference for operating above potential output). Regarding the variances of shocks (σ_ϵ^2, related to inflation, and σ_ϕ^2, related to output), T_2 also performs better across all levels of uncertainty, demonstrating greater resilience in high-volatility scenarios.

In conclusion, the transfer function T_2 consistently generates higher expected utility for the Central Bank in all simulated scenarios. These results validate Corollary 2, emphasizing the importance of adopting punishments based on deviations from the inflation target as an effective strategy to improve overall economic welfare.

Figure 1: Effects of parameter variation on the expected utility of the Central Bank



The conclusion we can take from this analyses is that both transfer functions achieve consistency through different incentives, and at first, it seams that punishing deviations from the target is a better strategy, since, in equilibrium, the prefered inflation policy is implemented, there are no transfers and the policy doesn't depend on personal preferences of the central banker.

4 Final Remarks

In this paper, we show that it's possible to eliminate the inflation bias and force a consistent policy even when the Central Bank has full independence in both instruments and goals in a perfect information setting by a commitment device analogous to Walsh (1995) transfer function. Two different transfer functions are able to implement a consistent policy, but making the transfer dependent on the deviations from the inflation target instead of the inflation level is preferable, for it implements the monetary authorities preferred monetary policy and is welfare superior. The next steps would be to incorporate extensions from traditional literature such as asymmetric information, production persistence, or cost to the transfers made by the principal, in order to test the robustness of the solution.

While our model assumes symmetric information, we acknowledge that relaxing this assumption would provide a richer and more realistic framework. For instance, under asymmetric information, private sector expectations would play a critical role in shaping the Central Bank's incentives and the resulting equilibrium. We leave the exploration of these extensions to future research.

Our analysis is based on a one-shot game, which provides a static framework for examining the design of incentive contracts. We recognize that extending the model to a dynamic setting could reveal additional dimensions of the problem, such as the role of reputation and the impact of historical deviations on future outcomes. For instance, in a repeated game, the private sector's reflections on the Central Bank's past behavior could influence the credibility of its announcements and its ability to commit to targets without explicit punishment mechanisms. Exploring these dynamic aspects is an important direction for future research.

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