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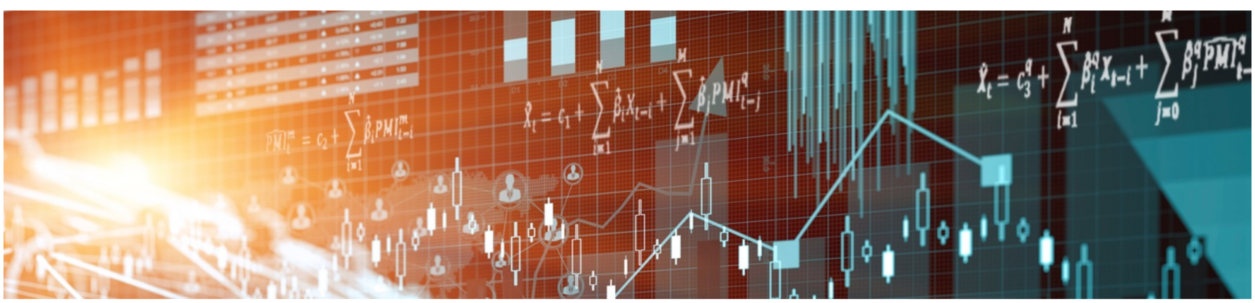

by Gino Cateau and Malik Shukayev

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Limited Commitment, Endogenous Credibility and the Challenges of Price-level Targeting

by

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Abstract

This paper studies the cost of limited commitment when a central bank has the discretion to adjust policy whenever the costs of honoring its past commitments become high. Specifically, we consider a central bank that seeks to implement optimal policy in a New Keynesian model by committing to a price-level target path. However, the central bank retains the flexibility to reset the target path if the cost of adhering to it exceeds a social tolerance threshold. We find that endowing the central bank with such discretion undermines the credibility of the price-level target and weakens its effectiveness to stabilize the economy through expectations. The endogenous nature of credibility also brings novel results relative to models with exogenous timing of target resets. A much higher degree of credibility is needed to realize the stabilization benefits of commitment. Multiple equilibria also emerge, including a low credibility equilibrium with frequent target resets and high volatility.

Bank topics: Monetary policy framework; Credibility; Inflation targets
JEL codes: E31, E52

Résumé

Dans cette étude, nous étudions les conséquences macroéconomiques de la décision d'une banque centrale de maintenir la possibilité de réaménager sa politique monétaire à chaque fois qu'il devient trop cher pour elle d'honorer ses engagements passés. Nous nous intéressons plus particulièrement au cas d'une banque centrale qui cherche à mettre en place une politique optimale dans un modèle néo-keynésien en s'engageant à maintenir sa cible de niveau de prix sur une certaine trajectoire. Cependant, la banque centrale se réserve la possibilité de redéfinir cette trajectoire si le coût entraîné pour y maintenir la cible dépasse un seuil de tolérance collectif. Donner à la banque centrale cette latitude rend la cible de niveau de prix moins crédible et réduit son incidence sur les anticipations et, donc, son pouvoir de stabilisation sur l'économie. La nature endogène de la crédibilité apporte des résultats inédits, par rapport aux modèles où les décisions de redéfinir la cible sont exogènes. Il faut une crédibilité beaucoup plus grande pour que l'engagement de la banque centrale produise les effets de stabilisation voulus. Des équilibres multiples se dégagent aussi, dont un équilibre de faible crédibilité caractérisé par de fréquents ajustements de la cible et une forte volatilité.

Sujets : Cadre de la politique monétaire; Crédibilité; Cibles en matière d'information
Codes JEL : E31, E52

Non-technical summary

Since Kydland and Prescott (1977), a central question for the design of monetary policy continues to be whether policy-makers should commit to a particular course of action, or retain the discretion to adjust policy as circumstances change. Commitment forces policy-makers to follow through on past promises, and in doing so, helps policy-makers manage expectations of private agents to generate better long-run outcomes for society. However, absent an institutional setting to hold the policy-maker accountable or reputation considerations that force the policy-maker to honour past promises, policy under commitment is time-inconsistent and may not be credible. Discretion, in contrast, frees the policy-maker from making such promises but is suboptimal, since it rules out the possibility that a policy-maker may be willing to make and keep ex-ante promises to induce stabilizing behaviour from private agents.

This paper studies the cost of limited commitment when a central bank has the discretion to adjust policy whenever the costs of honouring its past commitments become high. Specifically, we consider a central bank that seeks to implement optimal policy in a New Keynesian model by committing to a price-level target path. A price-level target path can implement fully optimal policy in our model since it inherits the history-dependent property of optimal policy (bygones are not bygones). However, the central bank retains the flexibility to reset the target path if the cost of adhering to it exceeds a social tolerance threshold (e.g., 5% of potential gross domestic product [GDP]).

We find that endowing the central bank with such discretion undermines the credibility of the price-level target and weakens its effectiveness to stabilize the economy through expectations. The endogenous nature of credibility also brings novel results relative to models with exogenous timing of target resets. First, there is a possibility of multiple equilibria with varying levels of policy credibility and macroeconomic volatility. Second, the levels of credibility would need to be relatively high to achieve the stabilization benefits of commitment. In our benchmark calibration, a target must not be revised for at least five years to derive 75% of the welfare benefits of commitment over discretion.

The paper also contributes to the recent debate over the need to rethink inflation targeting as a monetary policy framework in the post-crisis new normal of low neutral interest rates. Indeed, given the difficulties faced by inflation-targeting central banks to stimulate economic activity in the post-crisis environment and the risk that a world of low neutral rates will leave policy-makers with even less room to respond to adverse shocks, various authors have argued for history-dependent monetary policy frameworks such as price-level or nominal GDP-level targeting (Bernanke 2017, Williams 2017, Romer 2011). By committing to unwind past mistakes and return the price level (or nominal GDP level) to its pre-announced target path, price-level targeting (or nominal GDP-level targeting) would induce history dependence in policy-making and harness the power of expectations to provide additional stimulus (Vestin 2006). Our results suggest that the ability of price-level targeting (or nominal GDP-level targeting) to stabilize the economy by managing expectations hinges critically on the credibility of the central bank's commitment.

1 Introduction

Since Kydland and Prescott (1977), a central question for the design of monetary policy continues to be whether policy-makers should commit to a particular course of action, or retain the discretion to adjust policy as circumstances change. Commitment forces policy-makers to follow through on past promises, and in doing so, helps policy-makers manage expectations of private agents to generate better long-run outcomes for society. However, absent an institutional setting to hold the policy-maker accountable or reputation considerations that force the policy-maker to honour past promises, policy under commitment is time-inconsistent and may not be credible. Discretion, in contrast, frees the policy-maker from making such promises but at the same time is suboptimal, since it rules out the possibility that a policy-maker may be willing to make and keep ex-ante promises to induce stabilizing behaviour from private agents in the future.

In this paper, we consider a policy-maker that seeks to implement full commitment policy but retains some flexibility to diverge from past promises if the cost of honouring these promises going forward is too high. In particular, we consider a central bank that aims to implement full commitment policy in a New Keynesian model à la Gali (2008) via a price-level targeting rule. The full commitment plan in this model can be implemented through a price-level targeting rule since in response to an inflationary shock, it tolerates positive inflation but promises to generate future disinflation to undo the impact of the shock on the price level. If credible, the promise to undo the impact of shocks on the price level generates better macroeconomic outcomes, since private sector inflation expectations automatically adjust to stabilize the economy. However, the promise is also time-inconsistent, since once the inflationary shock abates, there is an incentive for the central bank to surprise private agents and not follow through on its promise to generate future deflation.

In our framework, the central bank commits to maintaining a price-level target path but retains the flexibility to reset its target path optimally at any time if the social cost of sticking to its target path going forward exceeds a pre-announced threshold (e.g., 5% of gross domestic product (GDP)).[1]

[1] Athey, Atkeson, and Kehoe (2005) and Waki, Dennis, and Fujiwara (2018) provide microfoundations for why it can be optimal for central banks to have constrained discretion when setting monetary policy. They argue that when central banks have private information (e.g., non-contractible information about the state or structure of the economy), giving central banks some flexibility over policy decisions implies that they can better use their private information to fine-tune policy for society's benefit. However, since too much flexibility can exacerbate the time-inconsistency issue, they also find that it is optimal to limit the amount of discretion by imposing bounds on the

The threshold then determines the probability that the central bank will reset its target path, and the extent to which the promise to maintain the target path is credible. We find that endowing the central bank with such an escape clause (i.e., the discretion to reset its target path) weakens the effectiveness of the price-level targeting rule in stabilizing the economy through expectations. Further, it can lead to multiple equilibria with varying degrees of credibility. Indeed, we find that it is possible to have a *higher credibility* equilibrium where the probability of the central bank resetting the target is small. But it is also possible to have a *lower credibility* equilibrium where the target is reset much more frequently and where inflation and output, as a result, become permanently more volatile.

The paper contributes to a recent literature examining the implications of imperfectly credible commitments for monetary policy. Schaumburg and Tambalotti (2007), Debortoli and Nunes (2010) and Debortoli, Maih, and Nunes (2014) analyze the benefits of commitment in models where policy-makers have a commitment technology, but with some exogenous and commonly known probability, they occasionally revise their plans. We extend this literature by endogenizing the timing of policy revisions. Indeed, in our model a price-level target serves as a commitment device. Policy-makers, however, have an option of resetting the target to a new optimal value, whenever the cost of returning the price level to the previously announced target, evaluated from that period onward, exceeds a given tolerance threshold. If the policy-maker has a high tolerance threshold, there is more commitment to the pre-announced target, and vice versa. Our model thus allows for differing degrees of endogenous credibility, in which full commitment and discretion are special cases. The endogenous nature of credibility brings some novel results relative to models with exogenous re-optimizations. First there is a possibility of multiple equilibria with varying levels of policy credibility and macroeconomic volatility. Second, the levels of credibility would need to be relatively high in order to attain a substantial fraction of the stabilization benefits of commitment. In our benchmark calibration, a target must not be revised for at least five years to achieve 75% of the welfare gain of commitment over discretion.

The paper also contributes to the recent debate over the need to rethink inflation targeting[2]

inflation rate. In our paper, we similarly assume that the central bank has constrained discretion in that it can only reoptimize its target path if the cost of maintaining the path exceeds a certain bound.

[2] Inflation targeting was officially introduced in New Zealand in 1990. It has since been adopted by 40 economies

as a monetary policy framework in the aftermath of the financial crisis. Indeed, given the difficulties faced by inflation targeting central banks to stimulate economic activity in the post-crisis environment and the slow recovery from the crisis in a number of economies, various authors have argued for history-dependent monetary policy frameworks such as price-level or nominal GDP-level targeting (Bernanke 2017, Williams 2017, Romer 2011, Frankel 2013). By committing to unwind past mistakes (bygones are not bygones) and return the price level (or nominal GDP level) to its pre-announced target path, price-level targeting (or nominal GDP-level targeting) would induce history dependence in policy-making and harness the power of expectations to provide additional stimulus (Vestin 2006). Our results suggest that the ability of price-level (or nominal GDP-level) targeting to stabilize the economy by managing expectations hinges critically on the credibility of the central bank's commitment.

The rest of this paper is organized as follows: section 2 presents our benchmark model. Section 3 derives the full commitment policy and shows how it can be implemented via a price-level targeting rule. Section 4 discusses how we model imperfect credibility. Section 5 presents our results and section 6 concludes. Some derivations and details regarding our computational procedure are collected in the appendix.

2 Simple New Keynesian model

Following Gali (2008), we assume a policy-maker that chooses the output gap, x_t, to minimize the social loss function

$$L = \frac{1}{2}\Omega E_0 \sum_{t=0}^{\infty} \beta^t \left[\hat{\alpha} x_t^2 + \pi_t^2\right], \tag{1}$$

where Ω and $\hat{\alpha}$ are positive parameters that are appropriately chosen to express social loss as a fraction of steady-state consumption,[3] $\pi_t = p_t - p_{t-1}$ is inflation, and p_t the log-price level. Inflation evolves according to the New Keynesian model

$$\pi_t = \beta E_t \pi_{t+1} + \kappa x_t + u_t, \tag{2}$$

including Canada, UK, Sweden and Norway.

[3] See Appendix A for the relationship between Gali's (2008) structural model, the reduced form equations, and parameters.

where β and κ are positive parameters and

$$u_t = \rho_u u_{t-1} + \varepsilon_t^u$$

is a cost-push shock with persistence $\rho_u \in (0, 1)$ and normally distributed innovations

$$\varepsilon_t^u \sim N\left(0, \sigma_u^2\right).$$

3 Optimal policy under commitment

Given the simple New Keynesian model above, following Clarida, Gali, and Gertler (1999), we can show that optimal policy under commitment would imply the following dynamics for the output gap and the price level:

$$\begin{aligned} x_t &= \delta x_{t-1} - \frac{\kappa\delta}{\eta\left(1 - \delta\beta\rho_u\right)} u_t \\ p_t - \bar{p} &= \delta\left(p_{t-1} - \bar{p}\right) + \frac{\delta}{1 - \delta\beta\rho_u} u_t, \end{aligned} \tag{3}$$

where the parameter δ is a positive parameter between zero and one[4] and $\bar{p}$ is the time-invariant average price level, which can be set at an arbitrary value.[5]

4 Imperfectly credible commitment to a target path

History-dependent monetary policy frameworks such as price-level targeting require the central bank to return the price level to publicly announced paths for the price level in response to shocks. Since such commitments may not always be feasible, in this paper, we consider a policy-maker that wants to derive some of the benefits of history dependence, but cannot perfectly commit to a target path for its target variable.

[4]See Appendix A for the relationship between the parameter δ and structural parameters.

[5]Under a trend-stationary labour productivity process, the results of this paper extend to a nominal income targeting framework as well.

Specifically, we consider a central bank that has the same period loss function

$$L_t = \frac{1}{2}\Omega\left[\hat{\alpha}x_t^2 + \pi_t^2\right]$$

as society. Rather than minimizing it on a period-by-period basis in a discretionary fashion (which would be suboptimal, as shown by Clarida, Gali, and Gertler 1999 and Vestin 2006), the central bank seeks to implement the optimal commitment path for the price level given by (3) but retain some discretion to reset the price-level target whenever the expected social cost of maintaining its target exceeds a certain tolerance level, denoted by $C > 0$. We can think of this option as the flexibility or constrained discretion given to the bank to act in the interest of the society if circumstances are such that trying to return the price level to the pre-announced target is deemed too costly.

To formalize the policy choice we can state the central bank's problem as follows:

$$V\left(p_{t-1} - p_{t-1}^T, u_t\right) = \min\left\{\frac{1}{2}\Omega\left[\hat{\alpha}x_t^2 + \pi_t^2\right] + I\left(p_t^T \neq p_{t-1}^T\right)C + \beta\mathbf{E}_t V\left(p_t - p_t^T, u_{t+1}\right)\right\} \tag{4}$$

subject to

$$\begin{aligned}
u_t &= \rho_u u_{t-1} + \varepsilon_t^u, \qquad \varepsilon_t^u \sim N\left(0, \sigma_u^2\right) \\
\pi_t &= \beta\mathbf{E}_t\pi_{t+1} + \kappa x_t + u_t \\
\pi_t &= p_t - p_{t-1}
\end{aligned}$$

$$\begin{aligned}
I\left(p_t^T \neq p_{t-1}^T\right) &= \left\{\begin{array}{c} 1,\ \text{if } p_t^T \neq p_{t-1}^T \text{ and} \\ 0, \text{otherwise} \end{array}\right\} \\
p_t - p_t^T &= \delta\left(p_{t-1} - p_t^T\right) + \frac{\delta}{1-\delta\beta\rho_u}u_t
\end{aligned} \tag{5}$$

That is, the target p_t^T is equal to its previous value p_{t-1}^T if there is no target reset in period t, or set at a new value if there is a target reset. Rewriting equation (5) as

$$p_t - p_t^T = \delta\left(p_{t-1} - p_{t-1}^T\right) + \frac{\delta}{1-\delta\beta\rho_u}u_t - \delta\left(p_t^T - p_{t-1}^T\right) \tag{6}$$

illustrates the impact that a target reset has on price-level dynamics. Indeed, the last term in (6) shows that a change in the target from the previous period will shift the price-level path from that point onwards.

4.1 Optimal target resets

By how much should the central bank adjust its target if it decides to reset it? In this paper, we assume that whenever the central bank resets its target, it does so optimally by choosing $\left(p_t^T - p_{t-1}^T\right)$ to optimize the continuation value of the central bank's value function.[6] Let us denote

$$\begin{aligned} \tilde{p}_t &\equiv p_t - p_t^T \\ \Delta p_t^T &\equiv p_t^T - p_{t-1}^T \end{aligned}$$

such that $\tilde{p}_t$ is the deviation of the price level from the time t target and Δp_t^T is the change in target from the previous period. We can reformulate the central bank's problem as:

$$V\left(\tilde{p}_{t-1}, u_t\right) = \min_{\Delta p_t^T}\left\{\frac{1}{2}\Omega\left[\hat{\alpha}x_t^2 + \pi_t^2\right] + I\left(\Delta p_t^T \neq 0\right)C + \beta\mathbf{E}_t V\left(\tilde{p}_t, u_{t+1}\right)\right\} \tag{7}$$

subject to

$$\pi_t = \beta\mathbf{E}_t\pi_{t+1} + \kappa x_t + u_t \tag{8}$$

$$\pi_t = \tilde{p}_t - \tilde{p}_{t-1} + \Delta p_t^T \tag{9}$$

$$\tilde{p}_t = \delta\tilde{p}_{t-1} + \hat{\delta}u_t - \delta\Delta p_t^T. \tag{10}$$

[6] In Masson and Shukayev (2011), the central bank is assumed to follow a simple reset rule whenever the social cost of not resetting the target exceeds C.

Using (9) and (10) to eliminate Δp_t^T, we can establish the restriction that target resets impose on the link between inflation and the deviation of the price level from target; namely,

$$\pi_t = \tilde{p}_t\left(1-\frac{1}{\delta}\right)+\frac{\hat{\delta}}{\delta}u_t.$$

As such, we can recast the problem as one where the central bank optimally chooses $\tilde{p}_t$ to

$$V\left(\tilde{p}_{t-1},u_t\right)=\min_{\tilde{p}_t}\left\{\begin{array}{c}\frac{1}{2}\Omega\left[\hat{\alpha}x_t^2+\pi_t^2\right]+I\left(\delta\tilde{p}_{t-1}+\hat{\delta}u_t-\tilde{p}_t\neq 0\right)C\\+\beta\mathbf{E}_tV\left(\tilde{p}_t,u_{t+1}\right)\end{array}\right\} \tag{11}$$

subject to

$$\begin{aligned}\pi_t &= \beta\mathbf{E}_t\pi_{t+1}+\kappa x_t+u_t\\ \pi_t &= \tilde{p}_t\left(1-\frac{1}{\delta}\right)+\frac{\hat{\delta}}{\delta}u_t.\end{aligned}$$

Given the non-linearity imposed by the central bank's decision of whether to reset the target or not, we use Tauchen's (1986) approach to discretize the state space and use a global collocation method, facilitated by Miranda and Fackler's (2003) CompEcon computational toolbox, to approximate the value and the optimal inflation functions. In Appenix C, we outline the solution procedure that we use to solve the central bank's problem of whether to reset the target, and conditional on resetting, the optimal reset value.

5 Results

We start by discussing the impact that endowing the central bank with an escape clause to reset its target has on inflation and output gap stabilization, and ultimately welfare. Remember that in our model, whether a central bank resets its target depends critically on its tolerance threshold, C, to the social cost of returning the price level to the previously announced target. To facilitate our analysis, we redefine the tolerance threshold in units of potential output as follows:

$$\frac{1}{2}\Omega\hat{\alpha}c^2 = C.$$

With this re-scaling, if the central bank's tolerance threshold is $100 \times c = 8$, the central bank would reset the target only if the social cost of returning the price level to the existing target exceeds 8% of quarterly (2% of annual) potential GDP in present-value terms. As we will see, the probability of that happening is very low. Conversely, if $100 \times c$ is small, say 0.01%, then target resets are very likely. The most interesting cases therefore lie for intermediate values of c for which the central bank faces a meaningful trade-off between resetting or not resetting the target. Our results in fact show that for a range of values of c, there are at least two stable equilibria with different unconditional probabilities of price target resets. We call the equilibrium with high (low) unconditional probability of price target resets the "lower (higher) credibility equilibrium".

5.1 Reset probabilities

Figure 1 shows how the unconditional price-level target reset probability changes with the tolerance level c expressed in percent of potential annual output. For very stringent escape clause rules, with the reset threshold in excess of 1.6% of annual output, there is only one equilibrium, in which the computed reset probability is zero (i.e., there are no price-target resets in the simulated sample). For very lax escape clause rules, with the reset threshold of less than 0.4% of annual output, there also appears to be only one equilibrium with the unconditional reset probability approaching 100% as the reset threshold is reduced to zero. Finally, for intermediate values of the reset threshold, there are at least two stable equilibria. We found these distinct equilibria by starting with two different initial guesses for the inflation function: one for the inflation function under the full commitment equilibrium ($c = \infty$), and one for the inflation function implied by the full discretion ($c = 0$) . The limit point $c = 0$ corresponds to full discretion, where the central bank is not constrained by its past choices of the price-level target. The limit point $c = \infty$ corresponds to full commitment equilibrium, where the price-level target resets are never optimal. The difference between unconditional reset probabilities in the lower and higher credibility equilibria reaches its maximum value of about 3.2

percentage points under the reset threshold of 0.6% of annual output.

5.2 The impact of target resets on welfare

Figure 2 plots the standard deviations of inflation for different values of c, normalized by the standard deviation of inflation in the full commitment benchmark; i.e., $\left(\frac{\sigma_\pi(c)}{\sigma_\pi(c=\infty)}\right)$. The vertical axis indicates that the volatility of inflation is strongly affected by changes in the stringency of escape clauses. For c close to zero, the standard volatility of quarterly inflation is nearly 55% larger than the standard deviation of quarterly inflation in the full commitment benchmark. When c exceeds 1.6% of potential GDP, the central bank never resets the target. Thus, for high values of the reset threshold c, the volatility of inflation corresponds to the one under the full commitment solution. Focusing on $c = .6$, the standard deviation of inflation is nearly 4% larger if the central bank has lower credibility than if it enjoys higher credibility $(1.45 \; - 1.41)$. These are substantial inflation volatility differences that arise entirely due to different levels of policy credibility.

Figure 3 plots the standard deviations of the output gap for different values of c, relative to the standard deviation of the output gap in the full commitment benchmark; i.e., $\left(\frac{\sigma_x(c)}{\sigma_x(c=\infty)}\right)$. The volatility of the output gap is not always decreasing in c. This non-monotonic relationship arises because there are two opposing effects of having a less stringent escape clause. On the one hand, a less stringent escape clause makes target resets more likely, which leads to higher volatility by destabilizing inflation expectations and the output gap. On the other hand, a less stringent escape clause lets the central bank act before the output gap becomes extremely large in absolute value, thus reducing the likelihood of large output fluctuations. The interaction of these two opposing effects results in a non-monotonic relationship between c and output gap volatility. Thus, while lax escape clauses moderate large output fluctuations, they also increase the frequency of medium-sized changes. We see, for instance, that around $c = 0.7$, the effort of the central bank to moderate output losses can even lead to lower output gap volatility in the higher credibility equilibrium than in the full commitment benchmark. In contrast, output gap volatility is nearly 4% higher in the lower credibility equilibrium. Nonetheless, for very high values of c, the standard deviation of the output gap converges to the full commitment benchmark, while for low values, it converges to the full discretion benchmark (with 5% higher output gap volatility).

Overall it seems like most of the volatility differences are borne by inflation rather than by output gap. This result is consistent with the previous findings of the literature, that monetary policy without commitment suffers from over-stabilization bias where small gains in stabilization of output are traded against large increases in the volatility of inflation (Rogoff 1985).

What do those volatility differences mean for welfare? Figure 4 plots net welfare losses for the two equilibria relative to the full commitment benchmark. To report the welfare losses associated with a particular policy regime, we use Gali's (2008) second-order approximation to welfare, which measures welfare losses in percentage points of steady-state consumption. We find that frequent nominal target resets that arise due to low policy thresholds c are very detrimental to welfare, relative to a full commitment equilibrium where there are no resets. For c close to zero, the net present welfare loss approaches 1.8% of annual steady-state consumption. For $c = 0.6$, the difference in welfare losses between lower and higher credibility equilibrium reaches more than 0.3% of annual steady-state consumption.

The key intuition for understanding these results is that the more credible the central bank's commitment to its price-level target is, the more it can exploit inflation expectations to stabilize the economy. Figure 5 illustrates this intuition by comparing the impulse response of expected inflation to a cost-push shock for different degrees of c, corresponding to a full commitment, full discretion, lower credibility and higher credibility equilibrium, respectively. Starting with the full commitment ($c = \infty$) scenario, we see that in response to a cost-push shock that increases the current level of prices, private agents expect lower inflation in the future. This is because when c is high, private agents fully believe that the central bank will honour its promise to reverse price-level surprises. Lower expected future inflation reduces the incentive to raise current prices, and stabilizes the economy by counteracting the current price increase. Thus, changes in expected inflation induced by the current price change stabilize the economy without requiring the central bank to change the current output gap by a large amount.

As c becomes smaller, private agents understand that the central bank is more likely to reset its price-level target, and as such is less bound to reverse price-level surprises. This is damaging in two ways. First, the expectations channel becomes weaker. This forces the central bank to rely more on output gap adjustments rather than expectations to stabilize the economy. Second, because of heavier reliance on output gap manipulations, it becomes costlier for the central bank to return the price level to an unchanged target. Price target resets look more attractive and, thus, price target resets become more likely. This further undermines the central bank's credibility and leads to self-fulfilling credibility problems for policy-makers and to multiple equilibria. We see those self-fulfilling forces at play for $c = 0.6$. Under the lower credibility equilibrium, private agents assign a higher probability to the central bank resetting the target than under the higher credibility equilibrium. This translates into a lower decline in expected inflation in subsequent periods.

When $c = 0$, private agents understand that the central bank has full discretion to reset the target at every opportunity. This negates the ability of the central bank to automatically stabilize the economy through expectations completely. Indeed, expected future inflation becomes independent of the current price level, forcing the central bank to rely completely on output gap adjustments to meet its stabilization objectives.

5.3 Endogenous versus exogenous target resets

From Figures 1 and 4, we see that even small unconditional reset probabilities can lead to large welfare costs. For example, when $c = 1.1$, the unconditional probability of price target resets is 3.2% and 4.8% in the lower and higher credibility equilibrium, respectively, but the welfare cost is fairly large, at 0.33% and 0.45% of annual steady-state consumption, respectively. This is because even if the unconditional target reset probability is small, the conditional target reset probability changes endogenously and becomes high whenever the deviation of the price level from the previously announced target increases. A lack of credibility in those periods leads to big fluctuations in inflation and output gap, which contribute disproportionately to the increase in the overall volatility. In this section, we showcase how the endogeneity of the target resets matters by comparing outcomes relative to a model where the target resets are exogenous, and occur with a fixed probability $P \in [0, 1]$ every period (see Appendix D for details regarding the model version with the exogenous probability of target resets).

Figure 6 shows how the welfare loss changes with the unconditional reset probability in three versions of the model. We find that for the lower credibility equilibrium with endogenous resets, welfare losses rise rapidly as the unconditional reset probability increases from zero to level off after an unconditional probability of about 35% is reached. Similarly, for the higher credibility equilibrium with endogenous resets, welfare losses also rise fairly rapidly. In contrast, in a model where resets are exogenous, welfare losses increase much more gradually. The main difference is that with the exogenous reset probability, there is no endogenous positive feedback between the level of macroeconomic volatility and the reset probability. The horizontal dotted line in Figure 6 traces the half-line for the welfare losses and shows that the exogenous reset probability can be as high as 49% per quarter before the central bank loses half of the commitment benefits relative to discretion. In contrast with the endogenous reset probability, the lower and higher credibility equilibria lose half of the commitment benefits around 12% and 18% reset probabilities. An alternative way to state these results is in terms of expected change between target resets. In a low credibility equilibrium with endogenous resets, the price-level target must be expected to last for approximately eight $\left(=\frac{1}{0.12}\right)$ quarters to achieve half of the welfare gain of full commitment over discretion. In contrast, with the exogenous target resets, the expected time between price-level target resets could be less than two quarters. The difference is even starker with larger cutoffs for the welfare gains. With the endogenous price-level target resets, an unrevised target must be expected to last at least six years to achieve 75% of the stabilization benefits of commitment. In contrast, the target only needs to last about a year in the exogenous reset model. These results highlight the important role of policy credibility for the price-level-targeting regimes.

6 Conclusions

This paper evaluates the desirability of history-dependent policy frameworks when the central bank cannot perfectly commit to maintaining a level target path. We consider a central bank that seeks to implement optimal commitment policy in a simple New Keynesian model via a price-level (or nominal GDP-level) target rule but retains the option to endogenously reset its target path if the social cost of not doing so exceeds a certain threshold.

We find that endowing the central bank with the discretion to optimally reset its target path weakens the effectiveness of the history-dependent framework to stabilize the economy through expectations. Indeed, even if the unconditional probability of price-level target resets is around 5%, the welfare cost can be as high as 0.45% of the annual steady-state consumption in a low credibility equilibrium.

Further, the endogenous nature of credibility brings novel results relative to models where the timing of target resets is exogenous. First, the central bank needs a high degree of policy credibility to realize the stabilization benefits associated with committing to a price-level target. In our benchmark calibration, the price-level target must be expected to last for more than two years to bridge half of the welfare gap between discretion and full commitment. Under the exogenous target resets, the target could be reset twice a year with the central bank still realizing half of the commitment benefits. Second, there is a possibility of multiple equilibria. Indeed, while it is possible to have a high credibility equilibrium where the probability of resetting the target is small, it is also possible to have a low credibility equilibrium where the target is reset much more frequently and where inflation and output are permanently more volatile.

References

Athey, S., A. Atkeson, and P. Kehoe. 2005. "The Optimal Degree of Discretion in Monetary Policy." *Econometrica* 73(5): 1431–75.

Bernanke, B. 2017. "Monetary Policy in a New Era." Brookings Papers on Economic Activity.

Clarida, R., J. Gali, and M. Gertler. 1999. "The Science of Monetary Policy: A New Keynesian Perspective." *Journal of Economic Literature* 37(4): 1661–1707.

Debortoli, D., J. Maih, and R. Nunes. 2014. "Loose Commitment in Medium-Scale Macroeconomic Models: Theory and Applications." *Macroeconomic Dynamics* 18(1): 175–98.

Debortoli, D. and R. Nunes. 2010. "Fiscal Policy under Loose Commitment." *Journal of Economic Theory* 145(3): 1005–32.

Frankel, J. 2013. "Nominal-GDP Targets, Without Losing the Inflation Anchor." In *Is Inflation*

Targeting Dead: Central Banking After the Crisis, edited by R. Baldwin and L. Reichlin, 90–94. London: Centre for Economic Policy Research.

Gali, J. 2008. *Introduction to Monetary Policy, Inflation, and the Business Cycle: An Introduction to the New Keynesian Framework*. Princeton, NJ: Princeton University Press.

Kydland, F. and E. Prescott. 1977. "Rules Rather than Discretion: The Inconsistency of Optimal Plans." *Journal of Political Economy* 85(3): 473–91.

Masson, P. and M. Shukayev. 2011. "Are Bygones Not Bygones? Modeling Price-Level Targeting with an Escape Clause and Lessons from the Gold Standard." *Journal of Macroeconomics* 33(2): 162–75.

Miranda, M. and P. Fackler. 2003. *Applied Computational Economics and Finance*. Cambridge, MA: MIT Press.

Rogoff, K. 1985. "The Optimal Degree of Commitment to an Intermediate Monetary Target." *Quarterly Journal of Economics* 100: 1169–89.

Romer, C. 2011. "Dear Ben: It's Time for Your Volcker Moment." New York Times (October 29).

Schaumburg, E. and A. Tambalotti. 2007. "An Investigation of the Gains from Commitment in Monetary Policy." *Journal of Monetary Economics* 54: 302–24.

Tauchen, G. 1986. "Finite State Markov-Chain Approximations to Univariate and Vector Autoregressions." *Economic Letters* 20(2): 177–81.

Vestin, D. 2006. "Price-Level Targeting versus Inflation Targeting." *Journal of Monetary Economics* 53(7): 1361–76.

Waki, Y., R. Dennis, and I. Fujiwara. 2018. "The Optimal Degree of Monetary-Discretion in a New Keynesian Model with Private Information." *Theoretical Economics* 13(3): 1319–67.

Williams, J. 2017. "Preparing for the Next Storm: Reassessing Frameworks and Strategies in a Low R-star World." Federal Reserve Bank of San Francisco Economic Letter, 2017-13.

Appendix A Gali's Model

In Gali (2008), the loss function is derived as a second-order approximation to the true, model-consistent utility function. It expresses social loss as a fraction of steady-state consumption:

$$W = \frac{1}{2}\frac{\varepsilon}{\lambda} E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{\lambda}{\varepsilon} \left(\sigma + \frac{\varphi + \alpha}{1-\alpha} \right) x_t^2 + \pi_t^2 \right], \tag{12}$$

where

$$\begin{aligned} \sigma &= -\frac{U_{cc}}{U_c} C \\ \varphi &= \frac{U_{nn}}{U_n} N \end{aligned}$$

$$\begin{aligned} \lambda &= \frac{(1-\theta)(1-\beta\theta)}{\theta} \times \Theta \\ \Theta &= \frac{1-\alpha}{1-\alpha+\alpha\varepsilon} \\ \varepsilon &> 1 \colon C_t(i) = \left(\frac{P_t(i)}{P_t} \right)^{-\varepsilon} C_t \\ \alpha &: C_t(i) = \exp(a_t) N_t(i)^{1-\alpha} \\ a_t &= \rho_a a_{t-1} + \varepsilon_t^a \end{aligned}$$

and θ is the Calvo parameter. For notational simplicity, denote the coefficient on the output gap in the social loss function as

$$\hat{\alpha} \equiv \frac{\lambda}{\varepsilon} \left(\sigma + \frac{\varphi + \alpha}{1-\alpha} \right).$$

The New Keynesian Phillips Curve (NKPC) equation is given by

$$\pi_t = \beta E_t \pi_{t+1} + \kappa x_t + u_t, \tag{13}$$

where

$$\begin{aligned}
\kappa &= \lambda\left(\sigma+\frac{\varphi+\alpha}{1-\alpha}\right) \\
x_t &= y_t-y_t^n \\
y_t^n &= \psi a_t+v \\
u_t &= \rho_u u_{t-1}+\varepsilon_t^u
\end{aligned}$$

and

$$\begin{aligned}
\psi &= \frac{1+\varphi}{\sigma(1-\alpha)+\varphi+\alpha} \\
v &= -\frac{(1-\alpha)(\mu-\log(1-\alpha))}{\sigma(1-\alpha)+\varphi+\alpha}>0 \\
\mu &= \ln\frac{\varepsilon}{\varepsilon-1}
\end{aligned}$$

The aggregate demand equation is

$$\begin{aligned}
x_t &= E_t x_{t+1}-\frac{1}{\sigma}\left(i_t-E_t\pi_{t+1}-r_t^n\right) \qquad (14) \\
r_t^n &= \rho+\sigma\psi E_t\left[\Delta a_{t+1}\right]=\rho+\sigma\psi\left(\rho_a-1\right)a_t \\
\rho &= -\ln\beta.
\end{aligned}$$

The parameter δ in equation (3), characterizing the dynamics of the price level under the optimal monetary policy, is given by $\delta=\frac{1-\sqrt{1-4\beta q^2}}{2q\beta}$, where

$$\begin{aligned}
q &= \frac{\eta}{\eta(1+\beta)+\kappa^2}, \text{ and} \\
\eta &= \left(\sigma+\frac{\varphi+\alpha}{1-\alpha}\right)\frac{\lambda}{\varepsilon}=\frac{\kappa}{\varepsilon}.
\end{aligned}$$

Appendix B Calibration

We set most structural parameters as in Gali (2008). The numerical values of the parameters are:

Parameter	Value
Discount factor, β	0.99
Relative risk aversion, σ	1
Inverse of Frisch elasticity, φ	1
Output elasticity for labour input, α	$\frac{1}{3}$
Constant elasticity of substitution, ε	6
Calvo probability, θ	$\frac{2}{3}$
Persistence of cost-push shocks, ρ_u	0.5
Persistence of productivity shocks, ρ_a	0.9

Finally, we calibrate the standard deviations of shocks remains. The standard deviation of productivity shocks is set to $\sigma_a = 0.01$ as in much of the business cycles literature. The standard deviation of cost-push shocks is set to match the standard deviation of the quarterly consumer price index (CPI) inflation rate in Canada during the inflation targeting period (roughly 0.4 percentage points from 1992:Q1 to 2007:Q2). To estimate the implied standard deviation of cost-push shocks, we assume that under inflation targeting the central bank follows a discretionary monetary policy. Under the discretionary monetary policy, the standard deviation of cost-push shocks is related to the standard deviation of inflation via the following relation:

$$std(\pi_t) = \frac{1}{\varepsilon\kappa + (1 - \beta\rho_u)} \frac{\sigma_u}{(1 - \rho_u^2)^{0.5}}.$$

Thus we find:

$$\sigma_u = std(\pi_t) \left(1 - \rho_u^2\right)^{0.5} [\varepsilon\kappa + (1 - \beta\rho_u)]$$

Appendix C Solution procedure

To solve for the policy-maker's decision to reset the target and conditional on the reset, the optimal value of the reset, we proceed with the following steps:

1. Take a grid over ranges of possible values $(\tilde{p}_{t-1}, u_t)$.

2. Guess functions

$$\begin{aligned} \pi_{t+1} &= f^0(\tilde{p}_t, u_{t+1}) \\ V_{t+1} &= g^0(\tilde{p}_t, u_{t+1}). \end{aligned}$$

3. For every pair $\tilde{p}_{t-1}, u_t$ from the grid, find $\tilde{p}_t^R$ solving the problem[7]

$$V^R(\tilde{p}_{t-1}, u_t) = \min_{\tilde{p}_t} \left\{ \frac{1}{2}\Omega\left[\hat{\alpha}x_t^2 + \pi_t^2\right] + C + \beta \mathbf{E}_t g^j(\tilde{p}_t, u_{t+1}) \right\}$$

$$\begin{aligned} \pi_t &= \beta \mathbf{E}_t f^j(\tilde{p}_t, u_{t+1}) + \kappa x_t + u_t \\ \pi_t &= \tilde{p}_t \left(1 - \frac{1}{\delta}\right) + \frac{\hat{\delta}}{\delta} u_t. \end{aligned}$$

4. Compare the above computed value $V^R(\tilde{p}_{t-1}, u_t)$ with

$$V^{NR}(\tilde{p}_{t-1}, u_t) = \frac{1}{2}\Omega\left[\hat{\alpha}x_t^2 + \pi_t^2\right] + \beta \mathbf{E}_t g^j\left(\delta\tilde{p}_{t-1} + \hat{\delta}u_t, u_{t+1}\right)$$

$$\begin{aligned} \pi_t &= \beta \mathbf{E}_t f^j\left(\delta\tilde{p}_{t-1} + \hat{\delta}u_t, u_{t+1}\right) + \kappa x_t + u_t \\ \pi_t &= \left(\delta\tilde{p}_{t-1} + \hat{\delta}u_t\right)\left(1 - \frac{1}{\delta}\right) + \frac{\hat{\delta}}{\delta} u_t. \end{aligned}$$

   and set

$$V(\tilde{p}_{t-1}, u_t) = \min\left\{V^R(\tilde{p}_{t-1}, u_t), V^{NR}(\tilde{p}_{t-1}, u_t)\right\}.$$

[7] Note, however, that the problem of finding $\tilde{p}_t^R$ is entirely forward looking, so $\tilde{p}_{t-1}$ is irrelevant for its solution.

5. Projecting resulting value and inflation functions on $(\tilde{p}_{t-1}, u_t)$, update the approximated functions

$$\begin{aligned}\pi_t &= f^{j+1}\left(\tilde{p}_{t-1}, u_t\right) \\ V_t &= g^{j+1}\left(\tilde{p}_{t-1}, u_t\right).\end{aligned}$$

6. Iterate on steps 3-5 above until convergence.

Appendix D Exogenous price-level target resets

Every period there is a probability P that the central bank is permitted to reset its target. The problem of the central bank in such periods can be stated as follows

$$V\left(\tilde{p}_{t-1}, u_t\right) = \min_{\Delta p_t^T} \left\{ \frac{1}{2}\Omega\left[\hat{\alpha} x_t^2 + \pi_t^2\right] + \beta \mathbf{E}_t V\left(\tilde{p}_t, u_{t+1}\right) \right\} \tag{15}$$

subject to

$$\begin{aligned}\pi_t &= \beta \mathbf{E}_t \pi_{t+1} + \kappa x_t + u_t \\ \pi_t &= \tilde{p}_t - \tilde{p}_{t-1} + \Delta p_t^T \\ \tilde{p}_t &= \delta \tilde{p}_{t-1} + \hat{\delta} u_t - \delta \Delta p_t^T.\end{aligned}$$

$$p_t - p_t^T = \delta\left(p_{t-1} - p_t^T\right) + \frac{\delta}{1 - \delta\beta\rho_u} u_t \tag{16}$$

where

$$\begin{aligned}\tilde{p}_t &\equiv p_t - p_t^T \\ \Delta p_t^T &\equiv p_t^T - p_{t-1}^T\end{aligned}$$

and the expected values $\mathbf{E}_t V(\tilde{p}_t, u_{t+1})$ and $\mathbf{E}_t \pi_{t+1}$ can be written as the weighted sums of Reset (R) and Non-Reset (NR) terms

$$\begin{aligned}
\mathbf{E}_t V(\tilde{p}_t, u_{t+1}) &= P\mathbf{E}_t V^R(\tilde{p}_t, u_{t+1}) + (1-P)\,\mathbf{E}_t V^{NR}(\tilde{p}_t, u_{t+1}) \\
\mathbf{E}_t \pi_{t+1} &= P\mathbf{E}_t \pi^R(\tilde{p}_t, u_{t+1}) + (1-P)\,\mathbf{E}_t \pi^{NR}(\tilde{p}_t, u_{t+1}).
\end{aligned}$$

To simplify the problem, we can eliminate Δp_t^T from the constraints above:

$$\begin{aligned}
\Delta p_t^T &= \tilde{p}_{t-1} + \frac{\hat{\delta}}{\delta} u_t - \frac{1}{\delta}\tilde{p}_t \\
&\Rightarrow \quad \pi_t = \tilde{p}_t - \tilde{p}_{t-1} + \tilde{p}_{t-1} + \frac{\hat{\delta}}{\delta} u_t - \frac{1}{\delta}\tilde{p}_t \\
&\Rightarrow \quad \pi_t = \tilde{p}_t\left(1 - \frac{1}{\delta}\right) + \frac{\hat{\delta}}{\delta} u_t.
\end{aligned}$$

Thus the problem becomes

$$V(\tilde{p}_{t-1}, u_t) = \min_{\tilde{p}_t}\left\{\frac{1}{2}\Omega\left[\hat{\alpha}x_t^2 + \pi_t^2\right] + \beta\mathbf{E}_t V(\tilde{p}_t, u_{t+1})\right\}$$

subject to

$$\begin{aligned}
\pi_t &= \beta\mathbf{E}_t\pi_{t+1} + \kappa x_t + u_t \\
\pi_t &= \tilde{p}_t\left(1 - \frac{1}{\delta}\right) + \frac{\hat{\delta}}{\delta} u_t.
\end{aligned}$$

$$\begin{aligned}
\mathbf{E}_t V(\tilde{p}_t, u_{t+1}) &= P\mathbf{E}_t V^R(\tilde{p}_t, u_{t+1}) + (1-P)\,\mathbf{E}_t V^{NR}(\tilde{p}_t, u_{t+1}) \\
\mathbf{E}_t \pi_{t+1} &= P\mathbf{E}_t \pi^R(\tilde{p}_t, u_{t+1}) + (1-P)\,\mathbf{E}_t \pi^{NR}(\tilde{p}_t, u_{t+1}).
\end{aligned}$$

In all other periods, when the central bank cannot change its target, the price level follows

$$\tilde{p}_t = \delta\tilde{p}_{t-1} + \hat{\delta}u_t - \delta\Delta p_t^T$$

with $\Delta p_t^T = 0$.

Appendix E Figures

Figure 1: Unconditional target reset probability for lower and higher credibility equilibrium

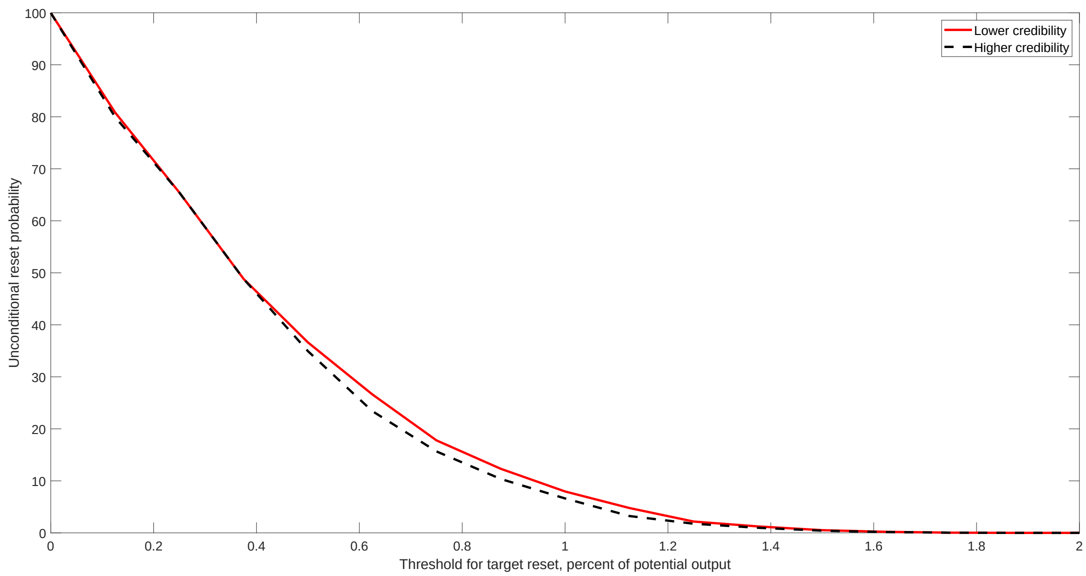

Figure 2: Volatility of inflation relative to full commitment benchmark

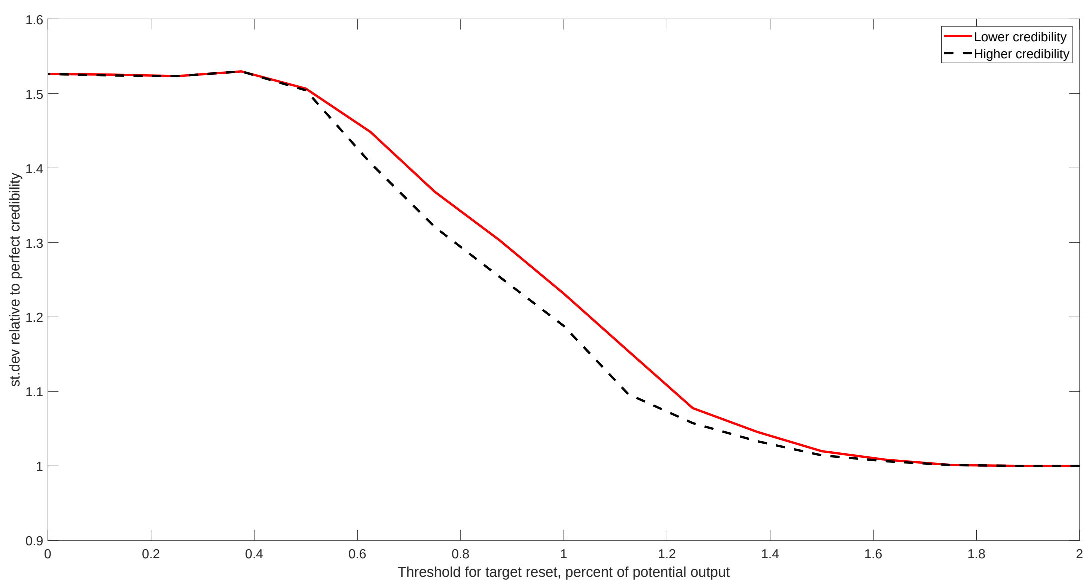

Figure 3: Volatility of output gap relative to full commitment benchmark

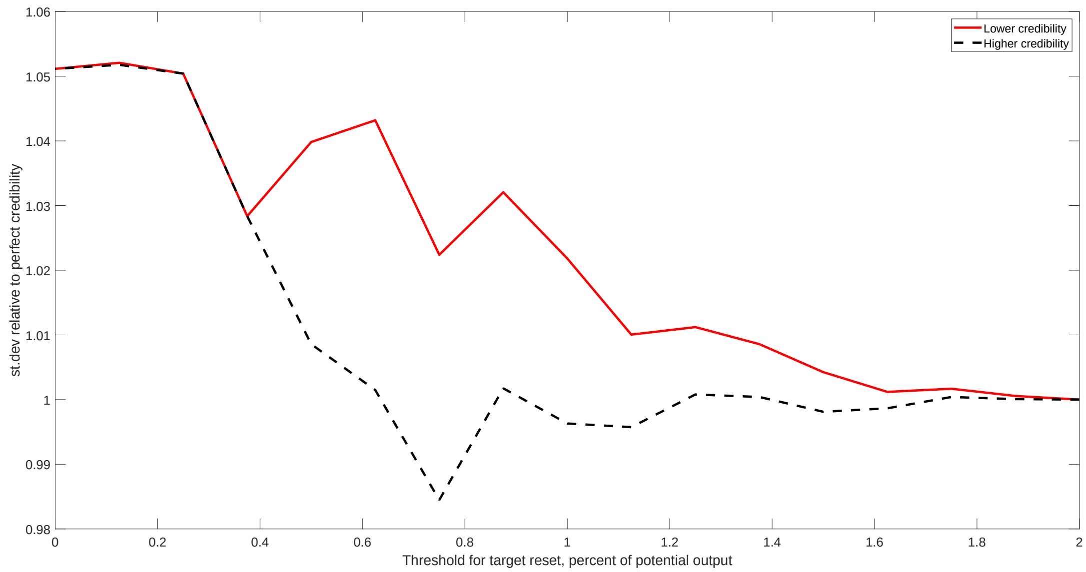

Figure 4: Welfare loss relative to full commitment benchmark

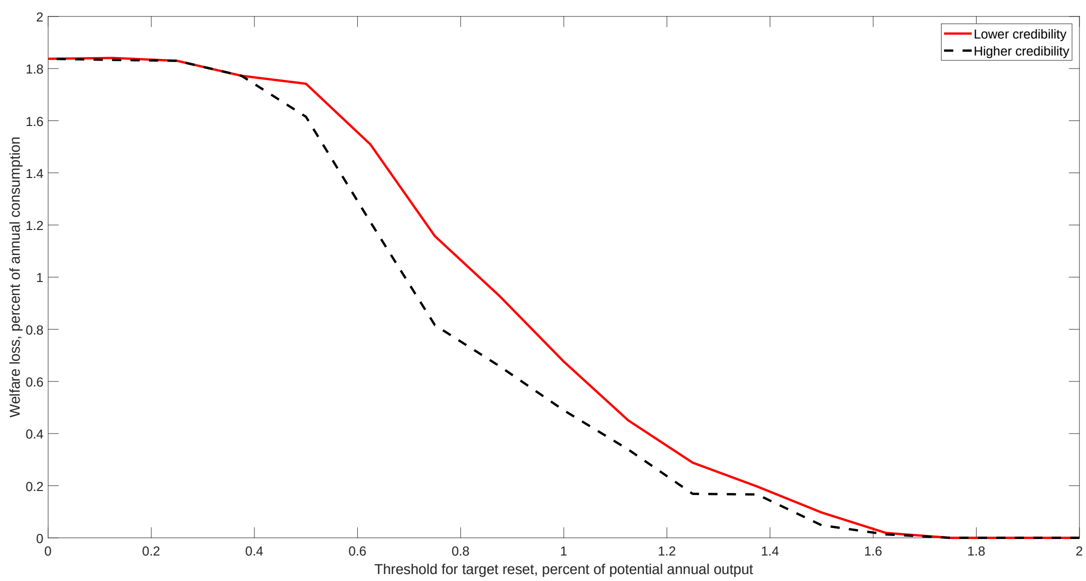

Figure 5: Response of expected inflation to a cost-push shock under different degrees of credibility

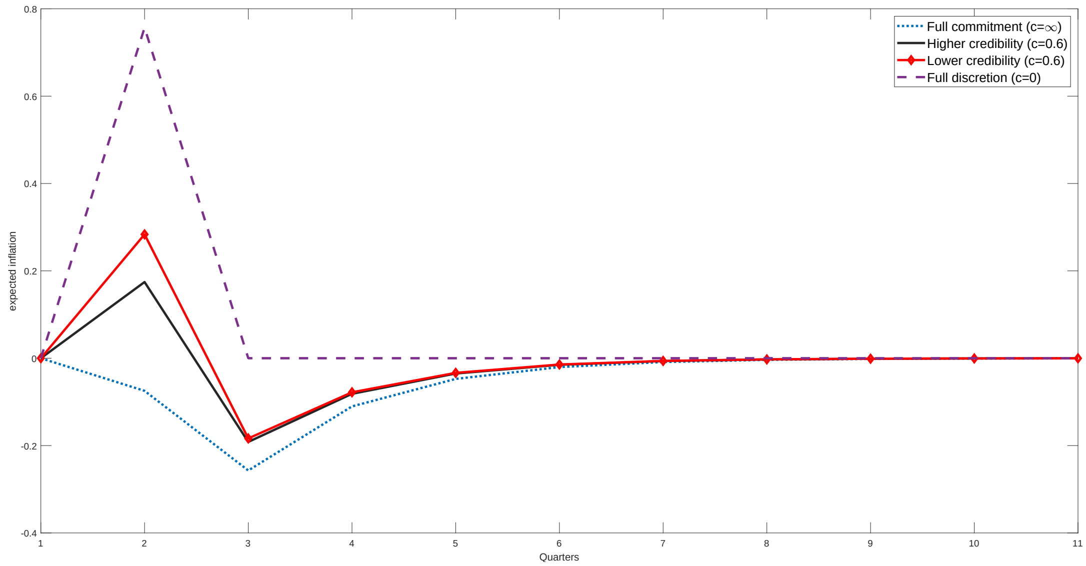

Figure 6: Impact of endogenous and exogenous target resets on welfare