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Credibility of History-Dependent Monetary Policies and Macroeconomic Instability

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Abstract

This paper evaluates the desirability of history-dependant policy frameworks when the central bank cannot perfectly commit to maintain a level target path. Specifically, we consider a central bank that seeks to implement optimal policy under commitment in a simple New Keynesian model via a price-level (or nominal GDP level) target rule. However, the central bank retains the option to 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. 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 10 years to bridge three quarters of the welfare gap between discretion and full commitment. Second, there is a possibility of multiple equilibria. Indeed, it is possible to have a high credibility equilibrium where the probability of resetting the target is small. But it is also possible to have a low credibility equilibrium where the target is reset much more frequently leading inflation and output to be permanently more volatile.

JEL classification: E31, E52

Key words: Monetary policy commitment, price-level targeting, nominal-income targeting, multiple equilibria, policy credibility

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*The views presented here are those of the authors and not necessarily those of the Bank of Canada or its staff.

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1 Introduction

Before the recent financial crisis there was a consensus in academic and policy circles that inflation targeting represents the best practice as a framework for setting monetary policy. Indeed, the commitment of a number of central banks to achieve an explicit numerical target for inflation[1] was often cited as a key reason why inflation expectations became well anchored in these economies (typically around a 2 per cent target), subsequently contributing to an environment with both low and stable inflation.

In the aftermath of the crisis, however, this wisdom is being questioned. Given the difficulties faced by central banks to stimulate economic activity in the post-crisis environment and the overall slow recovery from the crisis in a number of economies, critics of inflation targeting have been urging central banks to rethink how they conduct monetary policy. In particular, policy frameworks such as nominal GDP level targeting and price-level targeting have been proposed as superior alternatives to inflation targeting since they embody a commitment to unwind past mistakes (bygones are not bygones) which induces history dependence in policy-making and helps provide additional stimulus through expectations. Romer (2011), for instance, called for the Fed to adopt a nominal GDP level target in 2011. With nominal GDP in the U.S. undershooting its pre-crisis trend by more than 10 per cent at the time, Romer (2011) argued that the commitment to restore nominal GDP to its pre-crisis trend path would be a powerful way to communicate to the public that monetary policy would stay loose for a long time which would then boost inflation expectations, lower real interest rates and provide additional stimulus to the economy today. Likewise, Vestin (2006) shows that the ability of price-level targeting to induce history dependence in monetary policy can replicate fully optimal policy and help a central bank improve the inflation-output volatility trade-off relative to inflation targeting.

Whether history-dependent monetary policy frameworks can help a central bank better stimulate activity through expectations, however, depend critically on the extent to which the commitment of the central bank to do whatever it takes to return the target variable to its target path is credible. The public may doubt that the central bank would be willing to maintain its target path if returning the target variable to the target path implies inducing too much short-run volatility in the economy (e.g. would a central bank risk pushing an economy into deflation if the level of nominal GDP is well above target). Should concerns about the commitment of the central bank to maintain its target path at all times be important, the target path may become less effective as an anchor for private sector expectations. And if private sector expectations were to get de-anchored from the central bank's target path, the resulting volatility could make it very difficult for the central bank to maintain its target path.

This paper evaluates the desirability of a history-dependant policy framework in a world where the central bank cannot perfectly commit to maintain a target path at all times. Specifically, we

[1] Inflation targeting was officially introduced in New Zealand in 1990. It has since been adopted by more than 25 economies including Canada, UK, Sweden, Norway and more recently the U.S.

consider a central bank that seeks to implement optimal commitment policy in a New Keynesian model à la Gali (2008) via a price-level (or nominal GDP level) target rule. However, the central bank maintains the discretion to reset its target optimally if the social cost of not doing so, going forward, exceeds a certain threshold (e.g. 5 per cent of GDP). We find that endowing the central bank with such an escape clause i.e. the discretion to reset the target path for its target variable weakens the effectiveness of the history dependent framework to stabilize the economy through expectations. In fact, we find that such an escape clause can lead to multiple equilibria. Indeed, it is possible to have a high credibility equilibrium where the probability of the central bank resetting the target is small. But 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.

Our paper is related to the literature on monetary policy under imperfectly credible commitments on the part of monetary authority. Schaumburg and Tambalotti (2007) and Debortoli and Nunes (2014) analyze the benefits of commitment in models where policymakers 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. 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 existing target, evaluated from that period onward, exceeds a given tolerance threshold. By setting this tolerance threshold higher or lower, we can vary the degree of imperfect credibility. When the threshold is zero, there is no commitment. When the threshold is high, there is full commitment. Thus our model allows for differing degrees of endogenous credibility, in which commitment and discretion become special cases. The endogenous nature of credibility in our model 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 substantial fraction of stabilization benefits of commitment. In our benchmark calibration, an unrevised target has to be expected to last for 10 years to bridge 75% of the welfare gap between discretion and 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,[2] $\pi_t = p_t - p_{t-1}$ is inflation, and p_t the log-price level, given the New Keynesian model

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

Here 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 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 1:

$$\begin{aligned} \delta &= \frac{1 - \sqrt{1 - 4\beta q^2}}{2q\beta} \\ q &= \frac{\eta}{\eta\left(1+\beta\right) + \kappa^2} \\ \eta &= \left(\sigma + \frac{\varphi + \alpha}{1 - \alpha}\right)\frac{\lambda}{\varepsilon} = \frac{\kappa}{\varepsilon} \end{aligned}$$

and $\bar{p}$ is the time invariant average price level, which can be set at an arbitrary positive value.

[2] See section A of the appendix for the relationship between Gali (2008)'s structural model, the reduced form equations, and parameters.

Further, defining nominal income as

$$\begin{aligned} Y_t &= p_t + y_t \\ &= p_t + x_t + y_t^n \\ &= p_t + x_t + \psi a_t + v \end{aligned}$$

where y_t is current output, $y_t^n = \psi a_t + v$ is potential output (see section A of the appendix), a_t is a stationary labour productivity process

$$a_t = \rho_a a_{t-1} + \varepsilon_t^a, \qquad \varepsilon_t^a \sim N\left(0, \sigma_a^2\right),$$

the dynamic paths for the price level and output gap imply the following law of motion for nominal income

$$(Y_t - v - \bar{p}) = \delta\left(Y_{t-1} - v - \bar{p}\right) + \frac{\delta}{1 - \delta\beta\rho_u}\left(1 - \frac{\kappa}{\eta}\right) u_t + \psi\left(a_t - \delta a_{t-1}\right) \tag{4}$$

where v and ψ are parameters. Thus, under optimal policy, nominal income is stationary around its long-term value given by $\bar{Y} = \nu + \bar{p}$ as long as the labour productivity process a_t is stationary or at least trend-stationary. With a stationary labour productivity process, all of the results stated in this paper can be equivalently stated in terms of nominal income targeting. If a_t follows a unit root, however, fixed or trend-stationary nominal income targets would not be consistent with the optimal monetary policy, because the last term of the equation (4) would add a non-stationary component to the dynamics of optimal nominal income. In contrast, a price-level targeting with constant or trend-stationary targets would still remain optimal in this model, as there are no productivity components in the dynamics of optimal price level shown in the equation (3).

4 Imperfectly credible commitment to a target path

History-dependent monetary policy frameworks such as price-level (or nominal income) targeting require the central bank to return the price level (or nominal income) to publicly announced paths for the price level (or nominal income) 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 however cannot perfectly commit to a target path for its target variable.

Specifically, we consider a central bank that seeks to implement the optimal commitment path for the price level given by (3) but maintains the option to reset the price-level target whenever the expected social cost of not doing so (evaluated from that point in time onward) exceeds a certain tolerance level, denoted by $C > 0$. We think of that option as the discretion given to the bank "to act in the interest of the society" if circumstances are such that trying to return the price level (nominal income level) to the pre-announced target is deemed too costly.

We assume that the central bank has the same period loss function

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

as society, but is not free to minimize it on a period-by-period basis (which would be suboptimal given the absence of commitment, as shown by Clarida, Gali, Gertler 1999 and Vestin 2006). Instead, we assume that the central bank is *constrained* to set policy in a way that preserves the dynamics of the price-level in (3), but that the central bank resets the price-level target whenever the social welfare cost of not doing so exceeds a threshold value $C > 0$. So, in effect, the central bank has limited discretion in choosing its target, with the degree of discretion being parameterized by C. This setup can be interpreted as one where society imposes upon the central bank a constraint on the dynamic behavior for the price-level (nominal income).

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

$$V\left(p_{t-1} - p_{t-1}^T, u_t\right) = \min\left\{\frac{1}{2}\Omega\left[\hat{\alpha}x_t^2 + \pi_t^2\right] + I\left(p_t^T \neq p_{t-1}^T\right)C + \beta\mathbf{E}_t V\left(p_t - p_t^T, u_{t+1}\right)\right\} \tag{5}$$

subject to

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

$$\begin{aligned} I\left(p_t^T \neq p_{t-1}^T\right) &= \left\{\begin{array}{c} 1, \text{ if } p_t^T \neq p_{t-1}^T \text{ and} \\ 0, \text{otherwise} \end{array}\right\} \\ p_t - p_t^T &= \delta\left(p_{t-1} - p_t^T\right) + \frac{\delta}{1-\delta\beta\rho_u}u_t \end{aligned} \tag{6}$$

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.

Equation (6) can be re-written as

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

The last term on the right highlights the impact that a target reset has on price-level dynamics. A change in the target from the previous period will shift the price level path from that point onwards. By how much the central bank adjusts its target if it decides to reset the target depends on our assumption regarding the central bank's decision. In Masson and Shukayev (2011), the central bank is assumed to follow a reset rule whenever the social cost of not resetting the target exceeds

C. In contrast, 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. The next section shows how to derive the optimal vale of the target reset.

4.1 Optimal resets

Let us denote

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

and 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

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

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

$$V\left(\tilde{p}_{t-1}, u_t\right) = \min_{\tilde{p}_t} \left\{ \begin{array}{c} \frac{1}{2}\Omega\left[\hat{\alpha} x_t^2 + \pi_t^2\right] + I\left(\delta \tilde{p}_{t-1} + \hat{\delta} u_t - \tilde{p}_t \neq 0\right) C \\ + \beta \mathbf{E}_t V\left(\tilde{p}_t, u_{t+1}\right) \end{array} \right\} \tag{8}$$

subject to

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

In section C of the appendix, 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

As mentioned above, if the tolerance level C is very large, then the central bank is unlikely to ever reset the target. It is convenient to introduce another measure of the reset cost c, which is defined implicitly as:

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

Defining the cost in terms of $100c$ allows us to measure the reset cost in the same units as the output gap, i.e. in percentage points of potential output. For example, if $100 \times c$ is 10, then the central bank does not reset the target unless the cost of not resetting exceeds 10 percent of potential GDP (in present value terms). As we will see, the probability of that happening is very low. Conversely, if $100 \times c$ is very small, say 1 percent, 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 price target reset probability the "Low (High) credibility" equilibrium.

Figure 1 shows how the unconditional price 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 percent 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 0.7 percent of annual output, there also appears to be only one equilibrium with the unconditional reset probability approaching 100 percent 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 Low and High credibility equilibria reaches its maximum value of 8.44 percentage points under the reset threshold of 1 percent of annual output. Let us now see the effects of these differences in reset probabilities on the volatility of inflation and output gap.

Figure 2 plots the standard deviations of inflation for different values of c, normalized to the standard deviation of inflation in the "Fully credible" benchmark ($c = \infty$).[3] The vertical axis indicates that the volatility of inflation is strongly affected by changes in the stringency of escapes clauses. For c close to zero the standard volatility of quarterly inflation is nearly 55 percentage points larger than the standard deviation of quarterly inflation in the full commitment benchmark. When c exceeds 2.1 percent 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 $c = 1$, the standard deviation of inflation is nearly 27 percentage points larger if the central bank has low credibility than if the central bank enjoys high credibility $(1.35 - 1.08 = 0.27)$. These are substantial inflation volatility differences arising entirely due to loss of policy credibility. Let us now look at the effects on the volatility of output gap.

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 "Fully credible" benchmark.[4] 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. Nevertheless, once again we can see that for very high values of c the standard deviation of the output gap is the same as in the case without escape clauses: i.e., the ratio of standard deviations is equal to 1. For very low values of c, the standard deviation of the output gap is four percent larger with the escape clauses than without them. The most interesting case is once again $c = 1$. For this target reset threshold, the "High credibility" equilibrium has a lower volatility of the output gap than full credibility benchmark. In contrast, the low credibility equilibrium has the standard deviation of output gap nearly 10 percentage points higher than in the full credibility benchmark. 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 "overstabilization bias" where small gains in stabilization of output are traded against large increases in the volatility of inflation (Rogoff 1997). Let us now look at the effects of these volatility differences on welfare.

Figure 4 plots net welfare losses for the two equilibria relative to the fully credible 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 $L = \frac{1}{2}\Omega E_0 \sum_{t=0}^{\infty} \beta^t \left[\hat{\alpha} x_t^2 + \pi_t^2\right].$

[3] That is $\frac{\text{st.dev.}(\pi_t(c))}{\text{st.dev.}(\pi_t(\infty))}$.

[4] That is $\frac{\text{st.dev.}(x_t(c))}{\text{st.dev.}(x_t(\infty))}$.

The equilibria with frequent nominal target resets, arising due to low policy thresholds c, perform considerably worse than full credibility benchmark. For c close to zero, the net present welfare loss approaches 1.5 percent of annual steady-state consumption. For $c = 1$ the difference in welfare losses between High and Low credibility equilibria reaches more than 1 percent of annual steady-state consumption.

What is the intuition for these results? A credible full commitment regime has the advantage, relative to discretionary policy, of stabilizing the economy through an inflation expectation channel. Under the full commitment policy central bank reverses price level surprises. In fact the optimal policy can be framed as the price-level targeting regime, with an unchanged price level target. An increase in the current price level relative to target implies that the central bank will have to lower future inflation to bring the price level back to target. Lower expected future inflation lowers the incentive to raise current prices, and stabilizes the economy by counteracting the current price increase.[5] 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. This automatic stabilization mechanism is absent under discretion, since under discretion, the central bank does not explicitly target any price level. Thus, the expected future inflation under IT is independent of the current price level, and there is no negative feedback effect on expected inflation. As a result, the central bank has to rely solely on changes in the current output gap to meet its stabilization objectives.

Turning back to the policy regime with escape clauses, the positive probability of a price target reset weakens the link between the deviation from the current price target and expected future inflation. This is precisely because the central bank may reset the target so that monetary policy does not have to reverse past price shocks. The consequence of a weaker link between the current price and expected future inflation is that the automatic stabilization mechanism becomes less effective. This is damaging in two ways: first, since policy loses some of its automatic stabilization benefits, the central bank has to rely more on costly changes in the output gap to meet its objectives. 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 are more likely. This further undermines the central bank's credibility and leads to self-fulfilling credibility problems for policy makers and to multiple equilibria. In other words, escape clauses may have a perverse effect on public expectations, leading to higher output volatility and a costlier policy regime.

Another insight gained from Figures 1 and 4 is that even small unconditional reset probabilities can lead to large welfare costs. For example, when $c = 1.5$ percent, the unconditional probability of price target resets in the "Low credibility" equilibrium is only 2.7 percent, but the welfare cost is nearly 0.4 percent of annual steady-state consumption. This is because the conditional target reset probability changes endogenously and becomes high when the deviation of the price level from

[5] This negative feedback mechanism works in a symmetric way for price decreases relative to target.

target increases. Low policy credibility in those periods leads to big fluctuations in inflation and output gap, which contribute disproportionately to the increase in the overall volatility.

The important effects of endogenous price level target resets on macroeconomic volatility can be further illustrated by considering a model with exogenous target resets. The appendix D outlines the model in which the price level target resets happen with a fixed probability $P \in [0,1]$ per quarter. Figure 5 shows how the welfare loss changes with the unconditional reset probability in three versions of the model. The red solid line for the low credibility equilibrium with endogenous resets, shows that the welfare losses rise rapidly with the reset probability before leveling off and even declining slightly as the reset probability approaches 100 percent. The dot-dashed black curve with the circles, for the high credibility equilibrium with endogenous resets, shows that even under the high policy credibility the welfare losses rise fairly rapidly with the reset probability. Finally, the purple curve with the diamonds shows that the welfare losses increase much more gradually when the reset probability is exogenous. 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 dashed line in figure 5 traces the half-line for the welfare losses and shows that the exogenous reset probability can be as high as 55 percent per quarter before the central bank looses half of the commitment benefits relative to discretion. In contrast with the endogenous reset probability, the low and high credibility equilibria loose half of the commitment benefits at just 7 and 17 percent 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 14 $\left(=\frac{1}{0.07}\right)$ quarters to bridge a half of the welfare gap between discretion and full commitment. In contrast, with the exogenous target resets, the expected time between price level target resets could be less than two quarters to bridge a half of the welfare gap between discretion and full commitment. The difference is even starker with larger cutoffs for the welfare gains. With the endogenous (exogenous) price-level target resets an unrevised target has to be expected to last for 10 years (less than a year) to bridge 75% of the welfare gap between discretion and commitment. These results highlight the important role of policy credibility for the price-level-targeting or the nominal income targeting regimes.

6 Conclusions

This paper evaluates the desirability of history-dependant policy frameworks when the central bank cannot perfectly commit to maintain 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 as low as 2.7 percent, the welfare cost can be as high as 0.4 percent 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 3.5 years to bridge a 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 a 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.

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7 Figures

Figure 1: Unconditional nominal target reset probability for "High" and "Low" credibility equilibria

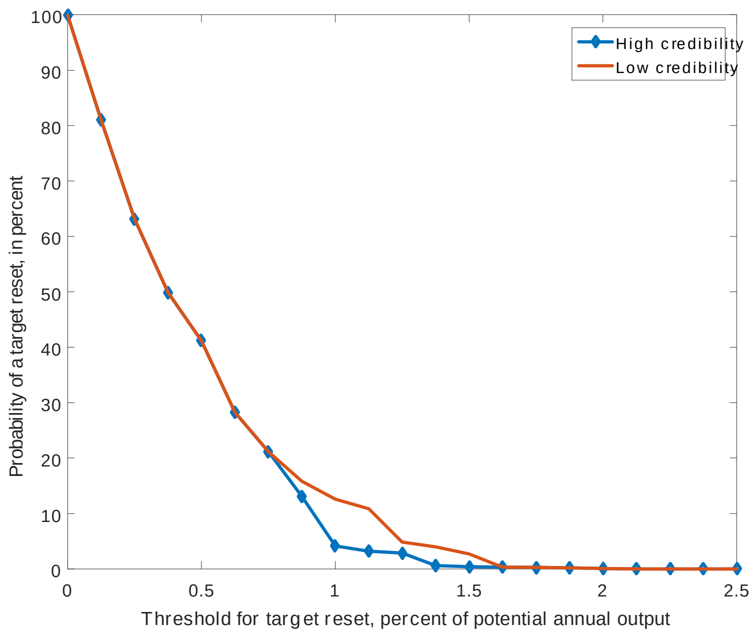


Figure 2: Volatility of inflation relative to full credibility benchmark

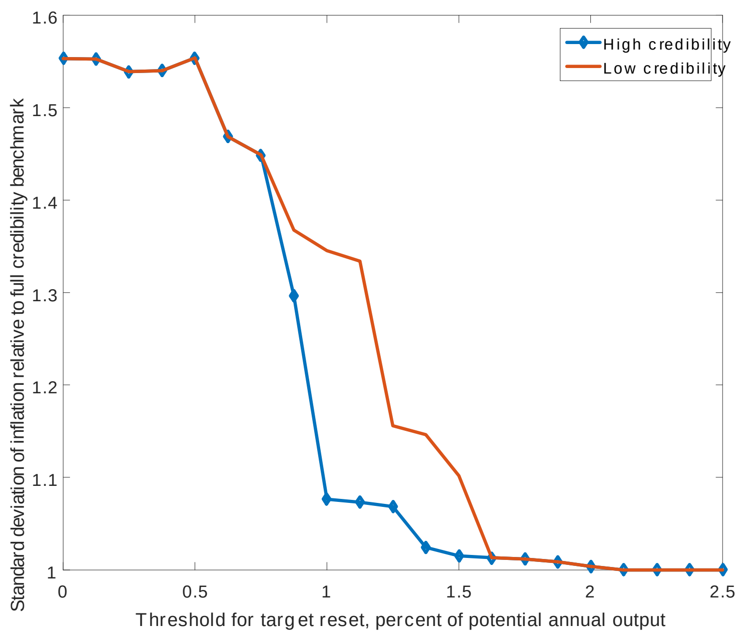


Figure 3: Volatility of output gap relative to full credibility benchmark

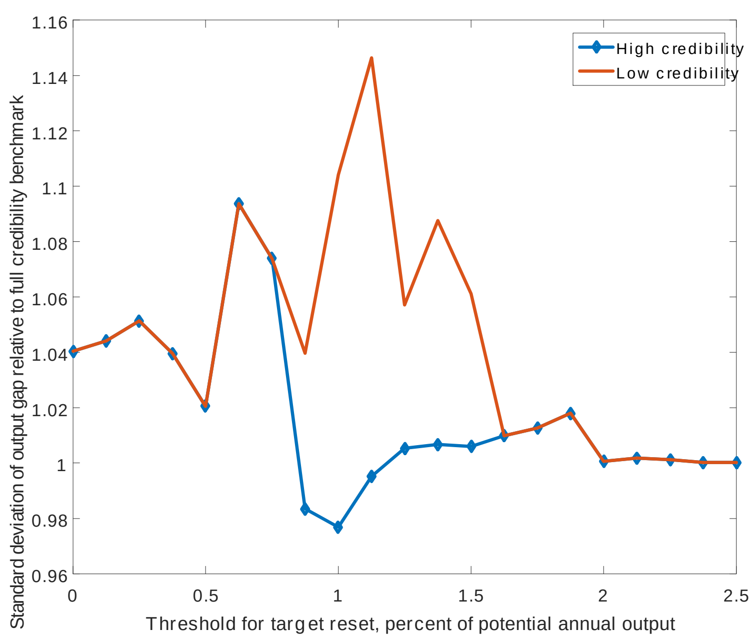


Figure 4: Welfare loss relative to full credibility benchmark

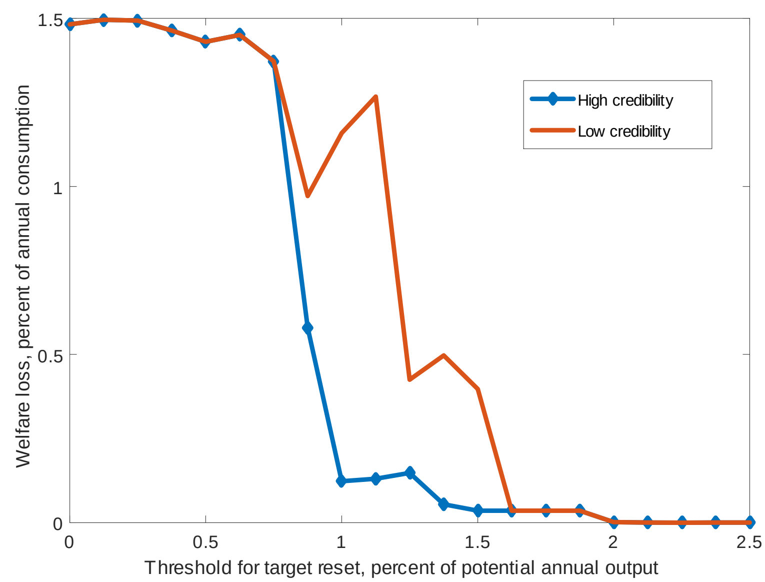
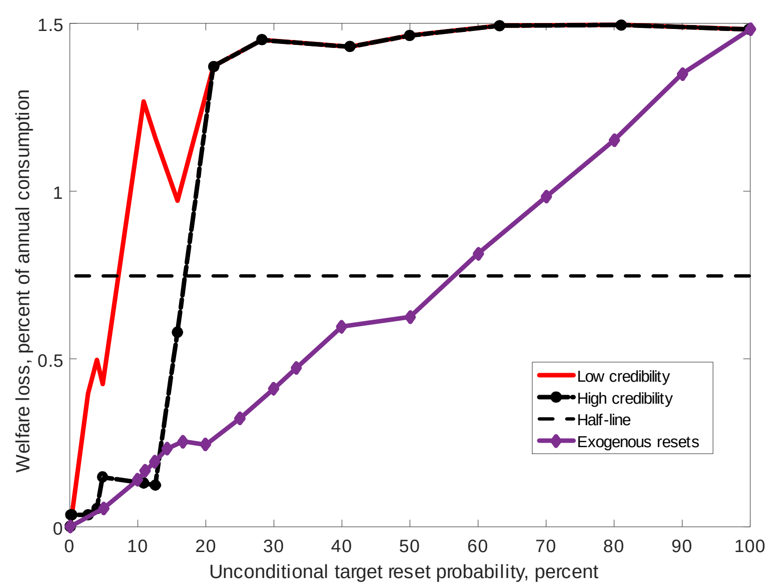


Figure 5: Welfare loss relative to full credibility benchmark, plotted against the unconditional reset probability



A Appendix: 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:

$$W = \frac{1}{2}\frac{\varepsilon}{\lambda}E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{\lambda}{\varepsilon}\left(\sigma + \frac{\varphi + \alpha}{1-\alpha}\right) x_t^2 + \pi_t^2 \right], \tag{9}$$

where

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

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

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 NKPC equation is given by

$$\pi_t = \beta E_t \pi_{t+1} + \kappa x_t + u_t, \tag{10}$$

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 IS equation is

$$
\begin{aligned}
x_t &= E_t x_{t+1} - \frac{1}{\sigma}\left(i_t - E_t\pi_{t+1} - r_t^n\right) \qquad (11) \\
r_t^n &= \rho + \sigma\psi E_t\left[\Delta a_{t+1}\right] = \rho + \sigma\psi\left(\rho_a - 1\right)a_t \\
\rho &= -\ln\beta.
\end{aligned}
$$

B Appendix: Calibration

We set most structural parameters as in Gali (2008)

$$
\begin{aligned}
\beta &= 0.99 \\
\sigma &= 1 \\
\varphi &= 1 \\
\alpha &= 1/3 \\
\varepsilon &= 6 \\
\theta &= 2/3 \\
\rho_e &= 0.0 \\
\rho_a &= 0.9
\end{aligned}
$$

It remains to calibrate the standard deviations of shocks. The standard deviation of productivity shocks $\sigma_a = 0.01$ is set as in much of the business cycles literature. The standard deviation of cost-push shocks is set to match the standard deviation of quarterly 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:

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

C Appendix: 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 in 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[6]

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

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

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

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

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

[6] 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.

tions

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

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

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

$$V(\tilde{p}_{t-1}, u_t) = \min_{\Delta p_t^T} \left\{ \frac{1}{2}\Omega\left[\hat{\alpha}x_t^2 + \pi_t^2\right] + \beta \mathbf{E}_t V(\tilde{p}_t, u_{t+1}) \right\} \tag{12}$$

subject to

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

$$p_t - p_t^T = \delta\left(p_{t-1} - p_t^T\right) + \frac{\delta}{1 - \delta\beta\rho_u} u_t \tag{13}$$

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

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

subject to

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

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

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 $\Delta p_t^T = 0$.

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