Why so gradual? Disinflation under inflation targeting

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Abstract

Central banks under inflation targeting (IT) typically pursue very gradual disinflationary policies despite the evidence that faster disinflations imply lower sacrifice ratios. This paper provides some rationale for the benefit of gradual disinflation using a standard New Keynesian (NK) model with a time-varying inflation target with imperfect credibility and noisy target announcement. The main findings are: i) the model generates a meaningful sacrifice ratio without any additional friction; ii) Without price indexation, whether gradualism or "Cold Turkey" policy generates lower sacrifice ratio depends on the IT degree of credibility; iii) In the baseline calibration for IT countries pursuing disinflation, gradualism has lower disinflation costs as inflation expectation is more aligned with the target path than the "Cold Turkey" policy, which requires a less robust response of interest rates.

KEYWORDS: Inflation targeting, disinflation, inflation costs, gradualism, Cold Turkey.

JEL CLASSIFICATION: E52, E58, E32

1 Introduction

Over the last few decades several central banks introduced the inflation targeting (IT) as their primary monetary policy framework. Countries under the inflation targeting regime differ markedly in many ways. Their objectives when adopting IT are also likely to differ.

Figure 1 documents how headline consumer price inflation and inflation target evolved for 25 countries that adopted IT. The plot for inflation starts three years before the introduction of IT for better comparison. The Panels (a-c) divide the samples into high (higher than 14.5%), medium (between 5% and 9.5%), and low (equal or below 5%) initial targets.

This figure highlights some interesting patterns. First, most countries with low initial targets already had low inflation when they adopted the regime. Or they just left from a disinflation episode. In that case, those countries changed the regime to maintain inflation on low levels.

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Second, almost all countries with high and medium initial targets pursued gradual disinflation policies. They deliberately started with high targets and gradually decreased over the years until they set on a lower inflation target. Although with some volatility, most countries managed to bring inflation to lower levels.

Countries under IT seem to prefer choosing a gradual disinflation policy instead of a the "Cold Turkey" (CT, henceforth) strategy where the final level of inflation is immediately pursued.

However, when it comes to empirical studies on disinflation, there is plenty of evidence point to faster disinflations as a less costly alternative. The seminal work from Ball (1994) provides evidence that disinflations with lower duration are associated with lower sacrifice ratios, i.e., less output costs for each point of inflation decreased (see also Daniels et al.; 2005; Gonçalves and Carvalho; 2009; Gibbs and Kulish; 2017; Katayama et al.; 2019).

Given that evidence, it is perhaps surprisingly that central banks opt to pursue very gradual disinflation policies. The average duration is roughly 9 years with annual changes of roughly 0.9% for countries with high initial targets and 0.5% for countries with medium initial targets.

This paper propose a model to study gradualism or CT disinflation policies and understand under which circumstances each policy is more beneficial. I also evaluate the benefits of introducing the IT regime in terms of sacrifice ratio (SR, henceforth) during a disinflation.

The model is a standard New Keynesian model with nominal ridigities a la Calvo (1983) and imperfect credibility along the lines of Erceg and Levin (2003).[1] Two key extensions are proposed: i) allowing for gradual or immediate disinflation and ii) introducing a noisy announcement of the inflation target. They study Vocker's disinflation and consider a CT disinflation and abstract from any type of central bank communication.

Lack of credibility is a key issue for the monetary authority when adopting IT (see for instance, Minella et al. (2003) for Brazil, Cespedes and Soto (2007) for Chile, and Fraga et al. (2003) for emerging countries).

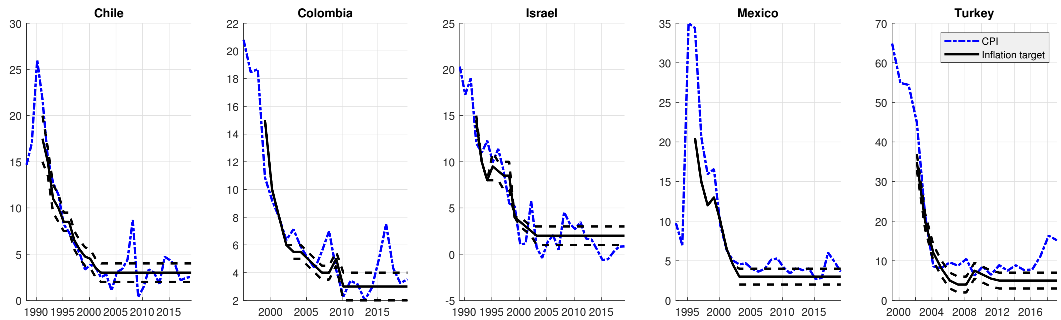
The standard imperfect credibility assumption as in Erceg and Levin (2003) is that the agents know that the central bank pursues a target but cannot observe the actual target. They cannot perfectly infer changes in the target because monetary shocks confound them.

Here, I refer to that benchmark as the Opacity case. The inflation targeting regime is represented by a noisy public signal about the target. This additional information helps to anchor inflation expectations toward the target. The signal's precision can be interpreted as the degree of transparency about the target (see Faust and Svensson; 2001, 2002) or a degree of distrust regarding the announced target. Thus, there is another lack of credibility.

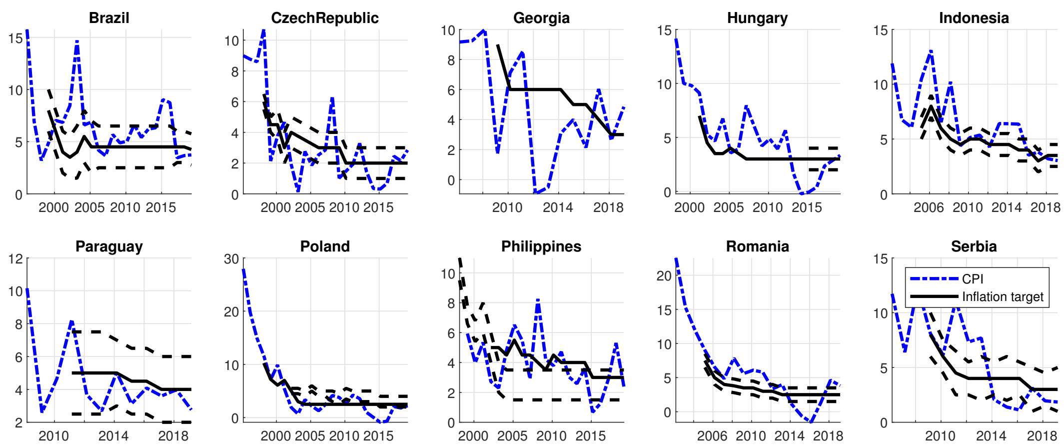
I also take into account non-zero steady-state inflation and consider different indexation schemes. Ascari and Sbordone (2014) shows that when steady-state inflation is positive, the standard as-

[1] Erceg and Levin (2003) study disinflation using staggered contracts a la Taylor.

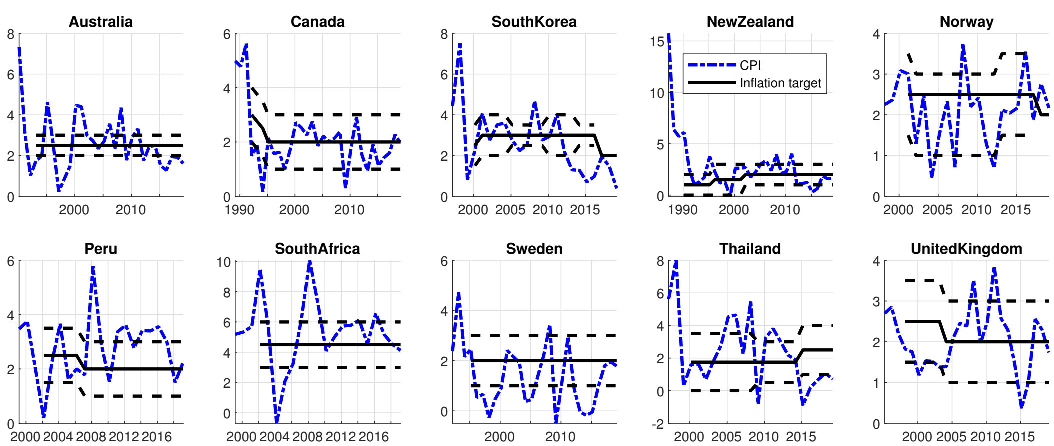
Figure 1: Gradual changes in inflation targets and headline inflation



(a) High initial target



(b) Medium initial target



(c) Low initial target

sumption of keeping prices fixed generates price dispersion, which may lead to sizeable output costs in the steady-state. Those permanent costs are at odds with the evidence of disinflation episodes discussed above.

I consider an indexation scheme that avoids permanent costs in terms of output. Non-optimizing firms index their prices using a combination of past inflation and their expectations about the target. Full indexation to either past inflation or target expectations are special cases.

Considering theses extensions, there are some key results as follows. Under full information, the SR for CT disinflation depends fundamentally on the the indexation scheme. Under target indexation, CT disinflation implies zero output costs as all firms change their prices aligned with the inflation target. However, there are sizeable costs in terms of output under full indexation to past prices.

Gradualism generates relatively small costs in terms of output in both types of indexation. It implies a path for inflation more aligned with the actual target, leading to a much less pronounced hike in real rates. Thus, whether gradualism generates less SR than CT depends on firms' indexation scheme.

In the model with imperfect credibility, another channel points toward gradualism that does not depend on the indexation scheme. Under Opacity, gradualism generates lower SR than CT in the baseline calibration. This result holds for all indexation schemes.

The mechanism is the following. Consider the target indexation benchmark (which has zero costs under full info) for simplicity. Even with a CT disinflation, firms slowly learn about the new target. In the baseline calibration, agents take almost seven years to learn the true target. Non-optimizing firms adjust prices by their target expectation. Other firms choose optimally to adjust prices by a lower inflation target as they benefit from better relative prices. Still, the inflation fall is much less pronounced than the target change, which requires stronger action from the central bank. This leads to a greater recession.

In contrast, a gradual disinflation is more consistent with learning about the new target. This implies a smaller inflation gap (difference between inflation and its target), requiring less action from the central bank.

Moreover, agents under IT observe a noisy public signal in addition to the interest rate decisions. That communication helps agents to learn about the new target without tighter monetary policy. Under the IT calibration, the learning process goes down to roughly four years. Compared with the Opacity case, IT implies lower costs in terms of output under both types of disinflation policies. As agents are better informed about the inflation target change, inflation expectations are better anchored to the new target level, which requires a less pronounced tightening from the central bank. This implies lower SR for IT compared to Opacity for both disinflation strategies. Assuming indexation by target expectations, whether CT or gradualism generate lower SR depends on the IT credibility. If the regime is sufficiently credible, an immediate drop in the target has a fast learning process and a weaker central bank response, leading to small output costs. This is consistent with the Sargent (1982) case for CT when the policy is credible. In the baseline calibration, the central bank's credibility is higher than this threshold, and gradualism has lower costs. Considering indexation by past inflation, gradualism generates a lower SR than CT, independently of the credibility degree of the IT regime. This happens because the disinflation costs due to mechanical indexation play a prominent role. In that case, gradualism has a better performance, as emphasized by Taylor (1983).

This paper is organized as follows. Section 1.1 discuss the related literature on disinflation costs, Section 2 presents the model. Then, section 3 presents the results and section 4 concludes.

1.1 Literature review

There is a long debate whether IT matters in terms of many outcomes. Ball and Sheridan (2004) provide evidence that IT countries have similar performance than non-IT countries. Lin and Ye (2007) confirm the results using propensity score matching methods (PSM).

Gonçalves and Salles (2008) and Lin and Ye (2009) find that developing countries under IT have lower and less variable inflation than non-IT. The former also find lower output variability.

The results for both groups are confirmed by de Mendonça and de Guimarães e Souza (2012) in a wider sample of 180 countries using PSM. However, most of the results are disputed by Ardakani et al. (2018) that uses a semiparametric PSM.

More related to the study here Gonçalves and Carvalho (2009) provide evidence that disinflations under IT have substantially lower sacrifice ratios than non-IT. However, BRITO (2010) reevaluates the study by showing that the results are not robust to time control effects as well some reclassification of the disinflation episodes under IT.

Regarding disinflation, Ball (1994) provides evidence that larger and faster disinflations are less costly for OECD countries. Daniels et al. (2005)

Interestingly, Mazumder (2014) confirms Ball's result for OECD including many other controls. But for non-OECD countries, the speedy of disinflation is not relevant for the sacrifice ratio. IT, after controlling for other factors did not seem to be relevant. Other characteristics such as trade openness and central bank independence are more relevant. Those factors were also emphasized by Daniels et al. (2005).

Ball (1995) shows that the combination of imperfect credibility and staggered prices generates meaninful disinflation costs. Bonomo and Carvalho (2010) show that the real effect depends crucially on the price rigidity and propose a endogenous time-dependent pricing that consider the disinflation policy. In those papers, imperfect credibility is related with a probability that the central bank stop pursuing the announced lower path for the money growth.

Here I propose modeling credibility within the IT regime. Agents do not fully trust the inflation target announced by the central bank. Instead, they receive a noisy public signal about the inflation target whose precision controls the degree of credibility of the inflation targeting regime. Agents also learn about the inflation target from interest rate decisions as in Erceg and Levin (2003). The central bank follows a Taylor rule with a target following a unit-root process and a standard monetary shock. Agents are rational and know the rule but cannot perfectly infer changes in the target because monetary shocks confound them. This modeling device is standard when studying changes in the monetary policy rule (see Erceg and Levin; 2003; Ireland; 2007; Andolfatto et al.; 2008; Cogley et al.; 2010; Del Negro and Eusepi; 2011)

Those papers assume that agents learn only from the interest rate, which I call Opacity case. The IT case is when agents learn from the interest rate and the noisy public signal. When the precision of this signal goes to zero, we go back to the Opacity case; when it does to infinity, we have a fully credible disinflation.

I also extend for a more general process for the inflation target that allows both CT and gradual disinflations. Those papers consider only immediate changes in the target.

Gibbs and Kulish (2017) also study gradual and CT disinflations with imperfectly credible announcements. The approach here differs in some important ways. First, they consider the target as an unknown parameter. Second, agents' expectations is a weighted average of the rational expectation and the adaptive learning. Thus, agents are learning about all parameters, including the inflation target.

Hagedorn (2011) shows the optimal disinflation in the NK model under full information. They consider a change in the immediate change inflation target and show that the optimal path for inflation is gradual. Here we consider gradual changes in the inflation target itself and the benefits under imperfect information.

2 Model

Apart from the introduction of an imperfectly observed inflation target, the framework in the following is a standard New Keynesian model with sticky prices and monopolistic competition. The central bank chooses the interest rate following a Taylor rule with a time-varying target that is not observed by the private sector.

Monetary authority

The central bank follows a nominal interest rate rule with partial adjustment according to

$$R_t = \bar{R}_t \left(\frac{\Pi_t}{\bar{\Pi}_t}\right)^{\phi_\pi} \left(\frac{Y_t}{\bar{Y}}\right)^{\phi_y} e^{\eta_t^r} \tag{1}$$

where $\bar{R}_t = r_{ss}\bar{\Pi}_t$ is the (gross) nominal interest rate consistent with the steady-state (gross) real interest rate $r_{ss} = 1/\beta$ and the (gross) inflation target, $\bar{\Pi}_t$. To avoid indeterminacy issues, I assume that $\phi_\pi > 1$.

η_t^r denotes a standard exogenous monetary shock and $\bar{\Pi}_t$ is the inflation target.

The key difference among those two shocks is their persistence. The monetary shock is a transitory shock that represents a change in the interest rate beyond the recommended by the rule. Is stochastic process is given by

$$\eta_t^r = \rho_r \eta_{t-1}^r + \varepsilon_t^r \tag{2}$$

In contrast, I assume that the inflation target follows an unit-root process given by

$$\begin{aligned} \bar{\pi}_t &= \bar{\pi}_{t-1} + \eta_t^\pi \\ \eta_t^\pi &= \rho_\pi \eta_{t-1}^\pi + \varepsilon_t^\pi, \quad \varepsilon_t^\pi \sim \mathcal{N}(0, \sigma_\pi^2), \end{aligned} \tag{3}$$

where $\bar{\pi}_t = log(\bar{\Pi}_t)$ is the inflation target rate. Thus, any change in η_t^π has a permanent effect on $\bar{\pi}_t$. Therefore, a target shift represents a permanent change in the conduct of monetary policy and in the rule itself.

In the "Cold Turkey" strategy, I consider that $\rho_\pi = 0$, such that the target follow follows a random walk and the shock ε_t^π has a immediate and permanent change in the target. $\rho_\pi > 0$ is consistent with a gradual disinflation consistent with the evidence shown in Figure 1.[2]

The inflation targeting regime requires not only following a target but also announcing the target to the public. Thus, I assume that a central bank that follows IT provides a noisy public signal about the inflation target given by

$$z_t = \bar{\pi}_t + u_t, \quad u_t \sim \mathcal{N}(0, \sigma_u^2). \tag{4}$$

The public signal is a modeling device to that represents the central bank communication the target. For simplicity, any strategic interaction between central banks communication and actions is abstracted. The central bank has an exogenous communication process and follows an interest rate rule.

In that case, σ_u is a measure of the degree of (lack of) transparency regarding the its target. When $\sigma_u = 0$, agents observe the true inflation target the model is the same as under full information. For a sufficiently high σ_u ($\sigma_u \to \infty$), the equilibrium with the public signal is exactly the same as one without the signal because it provides no useful information about the target.

[2]In general, the literature avoid using a unit root in the target, but use a highly persistent process in the target level as an approximation to preserve the steady-state inflation constant. In the log-linearization section I discuss how to deal with this technicality.

One interesting interpretation is that σ_u controls the tolerance bands around the inflation target, which is a common practice of central banks under inflation-targeting regimes. I use this idea to calibrate the value of σ_u.

Households

There is a continuum $h \in [0,1]$ of households whose utility function is given by

$$\sum_{s=0}^{\infty} \beta^s \left(log(C_{h,t+s}) - \frac{L_{h,t+s}^{1+\varphi}}{1+\varphi} \right), \tag{5}$$

where $0 < \beta < 1$ is the discount factor, γ is the inverse of the intertemporal rate of substitution, and φ is the inverse of the Frisch labor supply elasticity. $C_{h,t}$ and $L_{h,t}$ denotes household h's consumption and labor.

The composite consumption good is a Dixit-Stiglitz aggregator

$$C_{h,t} = \left(\int_0^1 (C_{h,i,t})^{(\varepsilon-1)/\varepsilon} di \right)^{(\varepsilon-1)/\varepsilon},$$

where $C_{h,i,t}$ is the consumption of each variety i in period t and $\varepsilon > 1$ is the elasticity of substitution between varieties.

The household h is subject to the budget constraint

$$P_t C_{h,t} + B_{h,t} \leq W_{h,t} L_{h,t} + R_{t-1} B_{h,t-1} + T_{h,t}, \tag{6}$$

in each period t. $B_{h,t}$ is an one-period nominal bond, $T_{h,t}$ denote net transfers and $W_{h,t}$ is the nominal wage.

Firms

There is a continuum $i \in [0,1]$ of monopolistic competition firms that produce a differentiated good Y_{it} using a production function

$$Y_{it} = L_{it}^{\alpha}, \tag{7}$$

where $\alpha \in (0,1]$. Introducing decreasing returns into the production function increases the so called "real rigidities" that help pricing decisions to be strategic complements.

As in Calvo (1983), in each period, there is a constant probability $(1-\theta)$ that each firm will re-optimize its price. The firms that do not optimize their prices are assumed to adjust their previous price with indexation rule

$$\Upsilon_{i,t} = (\Pi_{t-1})^{\iota} \left(E_{i,t}[\bar{\Pi}_t]\right)^{1-\iota}, \tag{8}$$

where $\iota \in [0,1]$ controls the degree of partial indexation and $E_{it}[\cdot] \equiv E[\cdot|\mathcal{I}_t^i]$ is the expectation operator of firm i conditional on the current information set, $\mathcal{I}_t^i$.

In the baseline model, I assume that $\iota = 0$, such that firms readjust by their expectation regarding the inflation target. As indexation is a common source of disinflation costs in the literature, I also consider the case that $\iota \in (0,1]$.

This assumption implies that the evolution of the price index is given by

$$P_t = \left[\theta \int_0^1 (\Upsilon_{i,t} P_{i,t-1})^{1-\varepsilon} + (1-\theta) \int_0^1 (P_{i,t}^*)^{1-\varepsilon} di\right]^{\frac{1}{1-\varepsilon}}, \tag{9}$$

where $P_{i,t}^*$ denotes the optimal price that firm $i \in [\theta, 1]$.

Firms maximize the expected discounted value of their real profit

$$E_{i,t}\left[\sum_{s=0}^{\infty} (\beta\theta)^s \left(\frac{\Upsilon_{t,t+s}^i P_{i,t}^* Y_{i,t+s|t} - W_{t+s} L_{i,t+s}}{P_{t+s}}\right)\right],$$

subject to the market clearing condition, $Y_{i,t} = \int_0^1 C_{h,i,t} dh$, the firm individual firm demand and the production function. $Y_{i,t+s|t}$ denotes output at period $t+s$ from firms that optimized their prices at period t and $\Upsilon_{t,t+s}^i$ is the updated indexation from t to $t+s$ given by

$$\Upsilon_{t,t+s}^i = \begin{cases} \prod_{j=1}^s \Upsilon_{i,t+j} & \text{if} \quad s \geq 1 \\ 1 & \text{if} \quad s = 0. \end{cases}$$

which is consistent with the indexation rule (8).

Information and timing

Firms and households do not observe the inflation target and the monetary shock. In the baseline model, agents learn about the inflation target through central bank decisions. They know the Taylor rule (1) and observe the interest rate R_t. Thus, the interest rate serves as a public signal.

In the following, I will refer to this baseline as the "Opacity" case, i.e., when the central bank does not communicate about the target. Thus, agents information set is given by

$$\mathcal{I}_{j,t}^O = \{R_\tau | \tau \leq t\},$$

where $j \in \{h, i\}$, $h \in [0,1], j \in [0,1]$.

In addition to the signals above, under the inflation targeting (IT) case, agents also observe the public signal (4), implying the information set

$$\mathcal{I}_{j,t}^{IT} = \{R_\tau, z_\tau | \tau \leq t\},$$

where $j \in \{h, i\}$, $h \in [0,1], j \in [0,1]$.

In other words, under Opacity, agents update their current view by observing central banks action, R_t. Under IT, they update both via its actions and communication, z_t.

To be consistent with this ideas, I assume the following timing protocol. Every period t is divided into two stages. In stage 1, the inflation target and monetary shocks, the signal realize, the central bank sets its interest rate. Firms set their price $P_{i,t}$ given their information, and (credibly) commit to satisfy the demand at the chosen prices. Households also decide their consumption $(C_{h,i,t}, C_{h,t})$, labor supply $L_{h,t}$ and demand for bonds, $B_{h,t}$, given their information. In stage 2, firms hire labor $L_{i,t}$ to produce and deliver the demanded quantity, $Y_{i,t} = \int_0^1 C_{h,i,t} dh$. Wages adjust to ensure that labor market clears, $\int_0^1 L_{h,t} dh = \int_0^1 L_{i,t} di$. Given the interest rate, demand for bonds equate with its supply, $\int_0^1 B_{h,t} dh = 0$.

2.1 Log-linearized model and solution

In this simple model, real variables are stationary, but this is not true for nominal ones. Since the inflation target has a unit-root, the growth rate of any nominal variable is non-stationary. Thus, it requires detrending inflation and the nominal interest rate before log-linearizing.

For linearization purposes, inflation is detrended as $\hat{\Pi}_t = \frac{\Pi_t}{\bar{\Pi}_t}$, such that $\hat{\Pi}_{ss} = 1$. Therefore, its log-linear deviation from steady-state is given by $\hat{\pi}_t = log(\hat{\Pi}_t) - log(\hat{\Pi}_{ss}) = log(\hat{\Pi}_t)$. The same applies for $\hat{r}_t = log(\hat{R}_t) - log(r_s s)$, where $\hat{R}_t = \frac{R_t}{\bar{\Pi}_t}$

One can recover the dynamics of inflation by

$$\begin{aligned} \pi_t = log(\Pi_t) &= log(\hat{\Pi}_t) + log(\bar{\Pi}_t) \\ &= \hat{\pi}_t + \bar{\pi}_t. \end{aligned}$$

The same idea applies to the nominal interest rate $r_t = \hat{r}_t + \bar{\pi}_t$.

Lowercase variables denote the log-linear deviation from the steady-state for real variables such as output, i.e., $y_t = log(Y_t) - log(Y_{ss})$; and denote log-deviation from the inflation target plus the target for nominal rates as in equation above.

Equilibrium

Despite the unit root in the inflation target, the model is quite standard. In the following, I present the equations in terms of actual inflation and nominal rates, instead of the their stationary counterpart.

The demand side of the model is given by the standard log-linearized Taylor rule and Euler equation below:

$$r_t = \phi_\pi \pi_t + \phi_y y_t - (\phi_\pi - 1)\bar{\pi}_t + \eta_t^r \tag{10}$$

$$y_t = E_t[y_{t+1}] - (r_t - E_t[\pi_{t+1}]) \tag{11}$$

The supply side of the model is given by

$$p_t^* - \upsilon_t = \frac{(1-\beta\theta)\Psi}{\theta} y_t + \beta E_t\left[p_{t+1}^* - \upsilon_{t+1}\right] \tag{12}$$

$$\upsilon_t = \iota \pi_{t-1} + (1-\iota)E_t[\bar{\pi}_t] \tag{13}$$

$$\pi_t = \theta \upsilon_t + (1-\theta)p_t^* \tag{14}$$

where $\Psi \equiv \frac{1+\varphi}{\alpha+(1-\alpha)\epsilon}$ is a parameter that encompasses the effects of output on wages via labor supply and the aggregation of individual marginal costs.

The inflation dynamics (14) and the optimal price (12) are commonly combined to find the dynamics of inflation as a function of its expectations and real output, which is known as the "New Keynesian Phillips Curve" (NKPC). Here, were also have to take into account the indexation rule (13) such that

$$\pi_t - \upsilon_t = \kappa y_t + \beta E_t[\pi_{t+1} - \upsilon_{t+1}]$$

where $\kappa \equiv \frac{(1-\theta)(1-\beta\theta)\Psi}{\theta}$ and indexation rule (13).

In absence of inflation target changes ($\bar{\pi}_t = 0$ for all t), the equation can be further simplified to the "hybrid NKPC" with backward and forward terms: $\pi_t = \frac{\iota\pi_{t-1}+\kappa y_t+\beta\mathbb{E}_t[\pi_{t+1}]}{1+\beta\iota}$ with $\mathbb{E}_t[\cdot]$ denoting the expectation under full information.

When indexation is fully on inflation target expectations ($\iota = 0$), we have a NKPC on the expected inflation deviation from target:

$$\pi_t - E_t[\bar{\pi}_t] = \kappa y_t + \beta E_t[\pi_{t+1} - \bar{\pi}_{t+1}]$$

3 Disinflation policies

The parameters are calibrated using standard values. The discount factor, $\beta = 0.99$, is such that annual interest rate is approximately 4%. The probability of not optimizing prices, $\theta = 2/3$, is set such that firms on average keep prices fixed by 3 quarters. The inverse Frisch elasticity is set to be consistent with the macro literature ($\varphi = 2.5$).

Moreover, the elasticity of substitution is chosen such that the firm's mark-up in the steady-state is 11% ($\varepsilon = 10$), following Woodford (2003). The labor share, α, is calibrated as 2/3, consistent with national account data of developed countries.

During the policy experiments, I compare the results with full indexation to past prices, $\iota = 1$, with full indexation to the expectations of the inflation target, $\iota = 0$.

For the monetary policy rule, I use standard values of $\phi_\pi = 1.5$ and $\phi_y = 0.5/4$. I consider a monetary shock with small persistence $\rho_m = 0.5$ and $\sigma_r = 0.15$.

For the CT disinflation, I set $\rho_\pi = 0.0$ and $\sigma_\pi = 0.065$. The latter is computed as follows. I first estimate ARIMA(0,1,0) using the interpolated quarterly inflation target from the Figure 1 for each country.[3] And then, take the average from all countries.[4] For Gradualism, I estimate a ARIMA(1,1,0) for each country. Using the same procedure, this leads to $\rho_\pi = 0.87$ and $\sigma_\pi = 0.028$.[5]

Most of the countries in Figure 1 adopt target bands.[6] The average band is roughly 1.25%. Since u_t has a normal distribution, we can compute this confidence interval around the actual target as

$$b/4 = |z_{\alpha/2}|\sigma_u \tag{15}$$

where $z_{\alpha/2}$ is the standard normal quantile from a α significance and $b/4$ is the band in quarterly rate. I set a $\sigma_u = 0.2717$ such that the public signal (4) has a 75% confidence band ($\alpha = 0.25\%$) and $b = 1.25$.[7] I also provide a sensitivity analysis using a grid for this key parameter.

A disinflation policy within the model in section 2 is a permanent decrease in the inflation target. I compute the impulse response functions after a shock with size $\varepsilon_t^\pi = 0.25(1 - \rho_\pi)$ to compare both policies generating the same final inflation target. Under CT ($\rho_\pi = 0$) is an immediate 1% drop in the annual inflation target, whereas the gradual policy ($\rho_\pi = 0.87$) reaches the same new

[3] I first apply to the quarters of each respective year the annual target. Then, I compute the 4-quarter rolling centered average to find a smoother change over quarters that are consistent with the annual changes.

[4] The estimates for σ_π range from 0.0149 for Paraguay to 0.2255 for Turkey.

[5] The estimates for σ_π range from 0.0098 for Paraguay to 0.063 for Turkey. For ρ_π, the estimates range from 0.629 for Philippines to 0.988 for Turkey.

[6] The exception is Georgia.

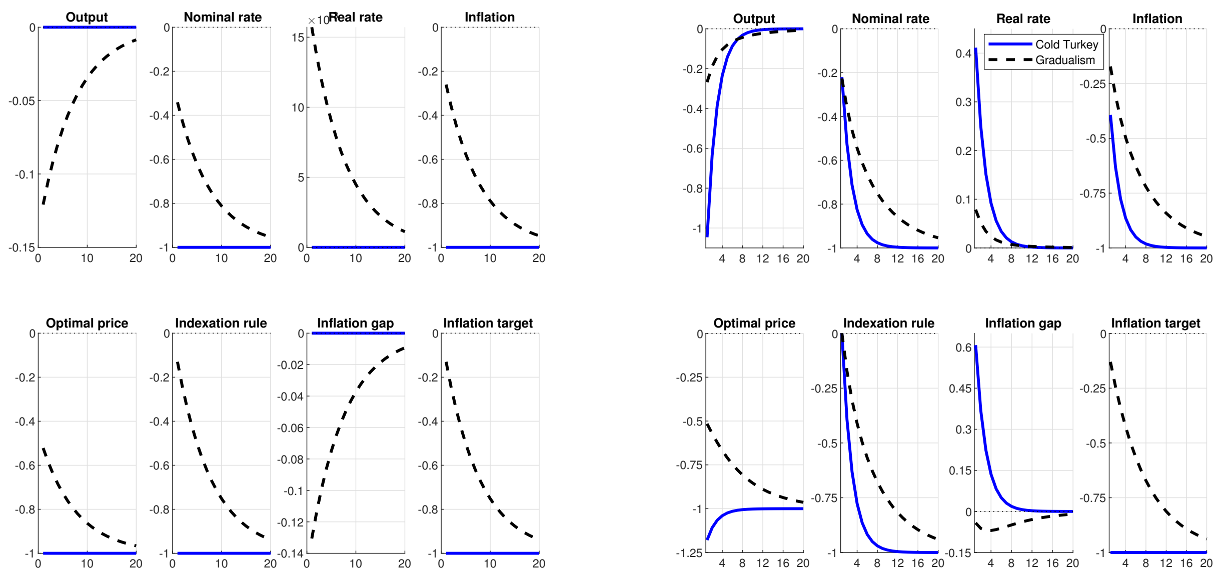
[7] As a reference, using the CPI and the bands from Figure 1, inflation is within the band roughly 40% of the time on average. However, details of each country's IT regime differ substantially in terms of target horizon, inflation measure, penalties when not complying, and other relevant aspects.

target over time.

3.1 Disinflation policies under full information

Figure 2 shows the impulse response functions (IRFs) from a 1% permanent decrease in the inflation target for both policies under indexation by inflation target expectations (Panel a) and indexation by past inflation (Panel b).

Figure 2: “Cold turkey” vs gradual disinflation under full information



(a) Indexation by target expectations ($\iota = 0$) (b) Indexation by past inflation ($\iota = 1$)

Note: All impulse response functions are multiplied by 4 to get annualized changes in percentage points.

Under full information, how costly the disinflation is and whether gradualism has lower output costs depend crucially on the indexation scheme.

Consider the CT disinflation under target indexation ($\iota = 0$) in the solid blue lines in Panel (a). In that case, firms that do not optimize adjust prices by the target. This is precisely the best response from firms that can optimize. Thus, inflation (and expectations) perfectly track the new target, and the nominal rate instantly drops by the same amount as the target. The real interest rate stays at steady-state level, generating zero output costs.

Nominal rigidity plays a major role when assuming indexation to past inflation ($\iota = 1$), as shown in the solid blue lines in Panel (b). Inflation does not immediately drop toward the target once firms that do not optimize prices use previous inflation to adjust their prices. Those firms are setting prices relatively higher than the ones that optimize. The latter firms consider this and decrease the inflation rate in their prices even more strongly than the fall in the target, benefiting from smaller relative prices.

This implies that inflation falls substantially, but not as much as the target. Despite the sharp increase in the inflation gap – which pushes the nominal rate upwards via the Taylor rule (10) – nominal interest rate falls by roughly 0.2%. This happens because the nominal rate also tracks the fall in the inflation target and also responds to the output gap.

Therefore, the rise in the nominal rate aligned with the drop in inflation expectations implies a sharp rise in the real rates of roughly 0.4%. Thus, output falls considerably (roughly 1% annually).

As inflation expectations adjust toward the new target, the nominal rate declines by the same amount, and the real rate and output gradually return to steady-state.

Now consider the black dashed lines in Figure 2 that represent the disinflation under gradualism. Under the baseline calibration, the target decreases by 0.13

Under indexation by the target, firms that do not optimize gradually adjust prices by the current inflation target. Optimizing firms push price adjustments even lower than the target fall as they anticipate that the target will decrease over time. This generates higher profits from higher demand from a better relative price. Thus, there is a slight negative inflation gap that leads to a small increase in the real rate given the central bank's response. There are small costs in terms of output, but higher than the zero cost benchmark from CT policy.

When considering indexation by past inflation, Panel (b) shows that gradualism generates a substantially lower recession associated than under CT. There are two key reasons. First, non-optimizing firms have an even more gradual response than under CT. Due to strategic complementarities, optimizing firms also cut prices more gradually. Second, as the inflation target decreases gradually, its path is closer to actual inflation than under CT. The inflation gap is even negative, contrasting with the sharp increase under CT. This opens room for an accommodative monetary policy which implies a much lower hike in the real rate and, thus, a milder recession.

The results suggest that CT has lower disinflation costs under indexation by the inflation target but higher costs when considering indexation by past inflation. Following most of the literature, I compare the sacrifice ratio (SR), which computes the cumulative loss of output during the disinflation episode divided by the decrease in inflation.

Since the model is log-linearized and IRFs are from a 1% decrease in the inflation target (and thus, inflation), we can compute the sacrifice ratio by

$$SR = \sum_{t=0}^{T^*} y_t$$

where T^* is the date where inflation converges to its lower steady-state and output gap stabilizes back to zero.[8]

Figure 3: Sacrifice ratio depending on indexation scheme

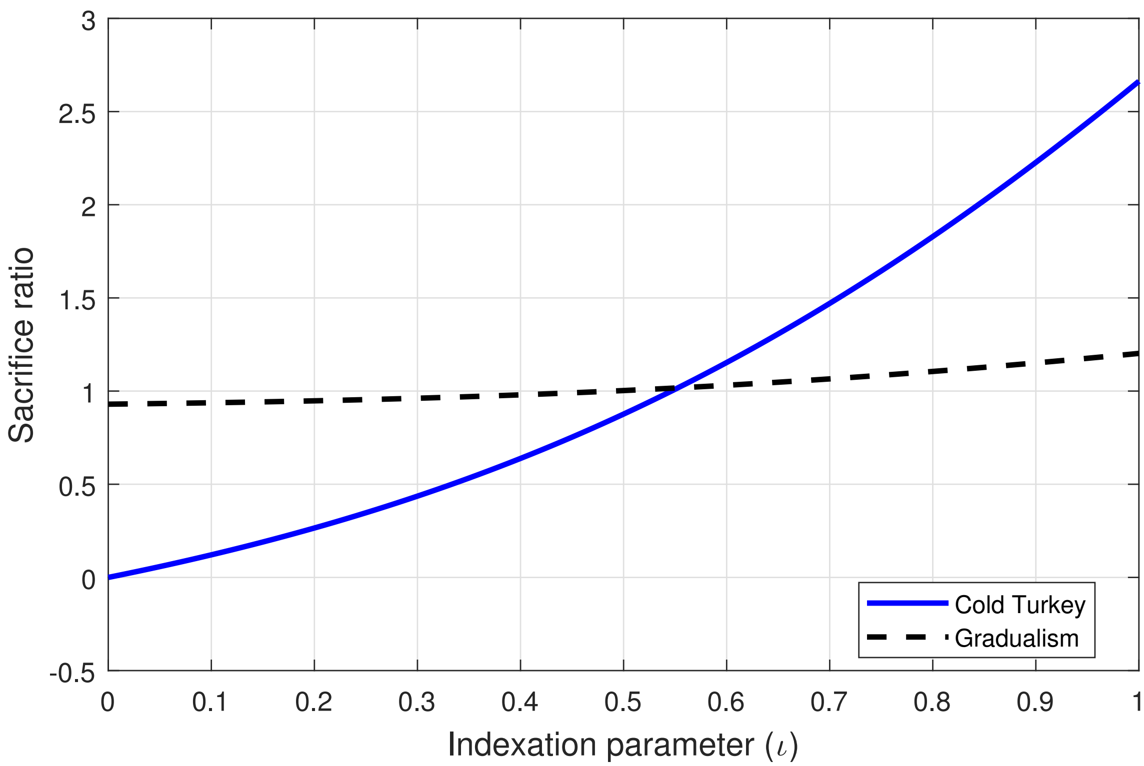


Figure 3 shows the sacrifice ratio (SR) under both disinflation strategies as a function of the indexation parameter ι. CT disinflation has a sacrifice ratio that ranges between zero to 2.66. Gradualism has a much more stable schedule, ranging from 0.93 to 1.20. In the baseline calibration, the SR is the same under CT or gradualism if the indexation has a similar weight on both inflation target and past inflation ($\iota \approx 0.55$).

Under target indexation, the gradual strategy does not fully take advantage that firms that do not optimize would select the best response to the target change.

On the other hand, under full indexation, gradualism generates much less dispersion in price choices, leading to inflation aligned with the actual target and a much less pronounced hike in real rates than under CT.

The results are consistent with the Taylor (1983) seminal paper that emphasizes the role of staggered indexed contracts for generating disinflation costs and making the case for gradual disinflation policies.

[8]For computations, I use $T^* = 100$.

The results are also in line with Ascari and Ropele (2012). They show that the full information model can generate realistic SR with a medium-scale DSGE model as in Christiano et al. (2005). Here, adding only the price indexation friction is sufficient to generate realistic costs.[9]

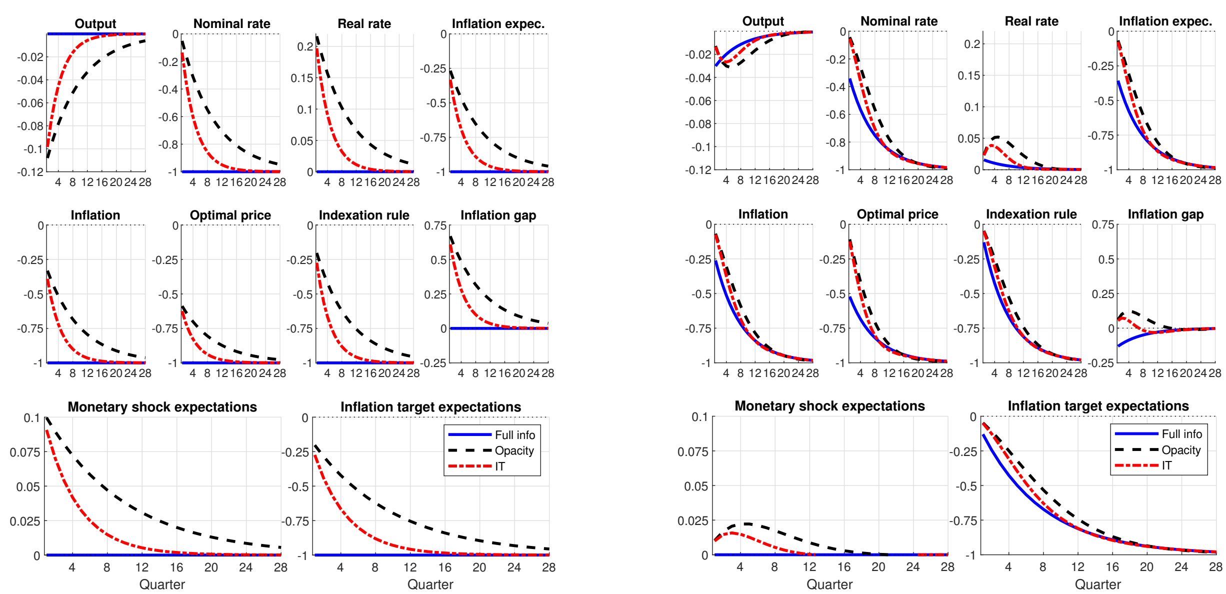
In countries under an IT regime, the target is more likely to become a focal point for price adjustments than in countries that follow an implicit target but do not announce it. If this reasoning is true, countries under IT have relatively lower ι. In that case, the full information model cannot explain why countries under IT pursue gradual disinflation, as shown in Figure 1 (a-b).

3.2 Disinflation policies under Opacity and inflation targeting

This section shows the results under imperfect credibility. For simplicity, I compare the Opacity and the IT cases using indexation via inflation target expectations only ($\iota = 0$). This benchmark has zero output costs for CT disinflation under full information. This leaves less room for explaining the preference for gradualism from IT countries.

Figure 4 shows the IRFs for the two alternative disinflation policies. The dashed black lines show the IRFs from the Opacity case and the red dotted lines under IT.

Figure 4: Disinflation policies under Opacity and IT with target indexation



(a) "Cold turkey" ($\rho_\pi = 0.0$)

(b) Gradualism ($\rho_\pi = 0.87$)

Consider CT disinflation from Panel (a). Unlike the full information benchmark, there are

[9]For instance, Gibbs and Kulish (2017) find an average SR of 3.08.

output costs from a CT disinflation under imperfect credibility. This is owing to a learning channel. Agents see that the interest rate decreases and inflation and output fall. They compute the exogenous effect of the shocks in the interest rate given by

$$\eta_t \equiv r_t - \phi_\pi \pi_t - \phi_y y_t = -(\phi_\pi - 1)\bar{\pi}_t + \eta_t^r.$$

Despite observing the fall in the interest rate, agents acknowledge the central bank's tightening, $\eta_t > 0$. They only do not know the source of the tightening: is it a temporary positive monetary shock or a permanent fall in the inflation target?

The optimal filtering from agents implies that agents expect a small positive monetary and a fall of roughly 0.25% in the inflation target on impact. As shown in the bottom right plot, expectations about the target slowly evolve. Under the baseline calibration, learning about the actual target takes more than seven years.

Firms that do not optimize follow their expectation about the target in their price setting, and firms that optimize drop prices even further, but less than the actual target, unlike the complete information benchmark.

In this case, inflation tracks the expectations about the target, which decreases about a quarter of the target's fall. This implies a positive inflation gap leading to a relatively higher nominal rate and hike in real rate, which depresses the economy.

Despite the indexation via target expectations (which leads to zero costs under full information), the Opacity case has substantial output costs, as shown in Figure 5. The SR is roughly 4.25, as shown in the dotted red horizontal line.

Under IT, the same policy generates a much better inflation-output trade-off than under Opacity: it ranges from zero to 4.25, as shown in the dashed red line. In the baseline calibration, it is roughly an SR of 1.75: 2.5 times lower than under Opacity.

A faster disinflation duration accompanies this lower cost: inflation converges to the new target after four years under IT, as shown in Figures 4.

This happens because the public signal (4) conveys additional information about the target, accelerating the learning process. Under the baseline calibration, it takes four years to learn the actual fall of the target (but most of the learning is already done after two years). This implies a smaller inflation gap that opens space for a lower nominal rate, leading to a weaker recession.

If $\sigma_u = 0$, the central bank announces the inflation target with full credibility and the IT is equivalent to the full information case. As $\sigma_u \to \infty$, the IT converges to the Opacity case, where agents learn about the target only by the central bank's actions. Thus, any degree of communication regarding the target is beneficial in terms of SR in a CT policy.

In Panel (b) from Figure 4 shows the dynamics under gradual disinflation for all models. As the inflation target decreases gradually, agents' expectation about the target is much closer to the truth than under CT. Under Opacity, this generates a weaker and hump-shaped rise in the inflation gap, implying much lower real rates and output than under CT. The blue dotted line in Figure 5 shows that SR stabilizes at 1.6, less than half of CT disinflation.

Surprisingly, either changing the target immediately or over roughly seven years, the disinflation episode under both policies have the same duration. In other words, it takes a similar time to fully implement the drop in *actual inflation* and its associated recession under Opacity. Without information from the central bank, the learning process takes several years under both strategies. However, under gradualism, there is a greater benefit from being more accurate about the target, translating into more accommodation monetary policy during those years.

Under IT for the baseline calibration, gains from gradualism are smaller but still economically relevant. The SR is 1.1 and 1.75 for gradualism and CT, respectively. It is worth noting that disinflation under gradualism takes roughly seven years to bring inflation to its new lower level and only four years under CT.

Under indexation using the expected inflation target, CT is less costly than gradualism under full information. And it is much more beneficial under Opacity. Since the IT equilibrium is between those two, there exists a credibility level of the IT that the central bank has the same SR under both policy strategies. Figure 5 shows the SR as a function of σ_u and this credibility threshold for the baseline calibration.

The solid blue and dashed red line cross roughly at $\sigma_u = 0.145$. For values lower than that, a central bank under IT has lower SR by conducting a disinflation under CT. For values higher than that, Gradualism has lower costs. This credibility threshold is roughly half of the baseline calibration.

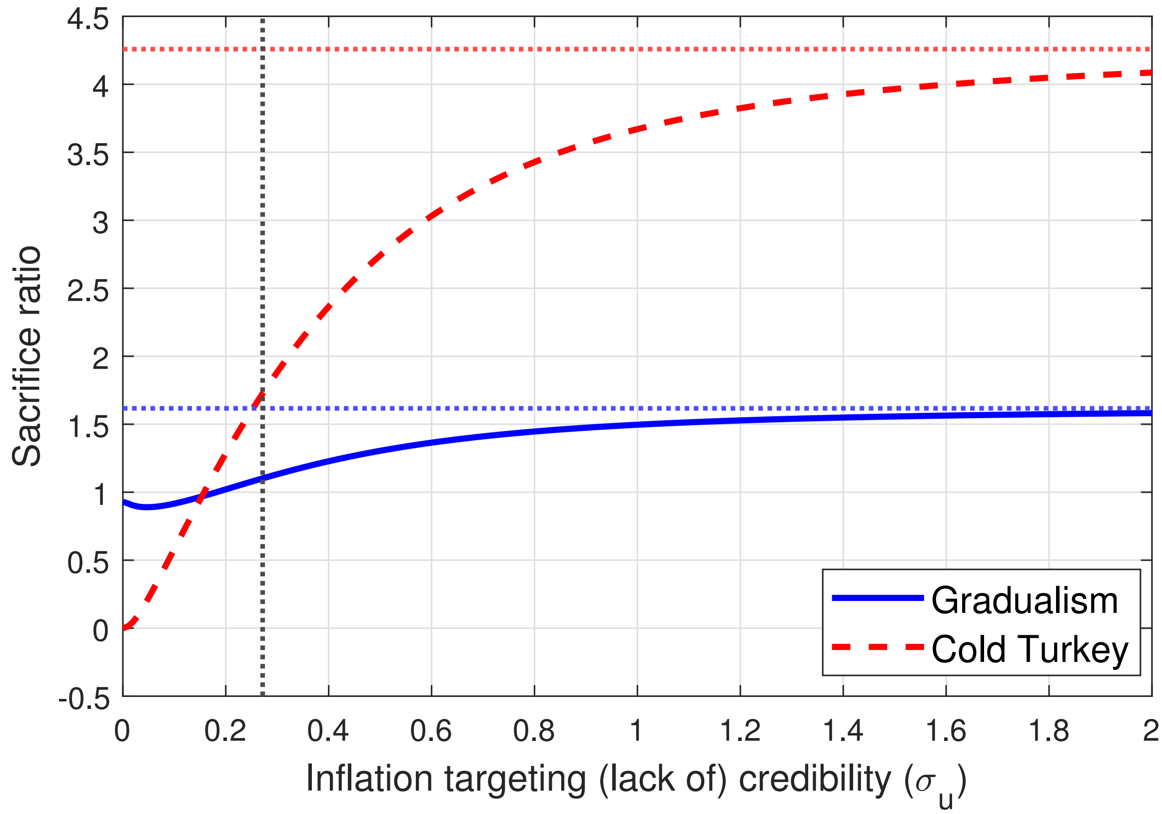
This is consistent with the Sargent (1982) case for CT when the policy is credible. The key difference is that author studies substantial changes in the policy regime. The idea is that drastic change in the policy regime would generate credibility and could immediately change inflation expectations without generating output costs.

Here, if the change in the target is sufficiently credible, agents understand the policy change faster and adjust inflation expectations accordingly. In that case, CT disinflation is more beneficial.

According to equation (15), the credibility threshold implies either a lower tolerance band or higher confidence for the same band. I use this logic to grasp how strong is this credibility requirement. In the first alternative, it would be a band of 0.67%, which is roughly half of the baseline choice. Otherwise, the 1.25% band would have to be consistent with a 0.985% confidence area in the normal distribution of u_t, which leads to a small room for deviations of inflation from the band.

Therefore, the baseline calibration suggests that IT countries prefer to pursue gradual disinfla-

Figure 5: Sacrifice ratio depending on IT credibility



Note: The sacrifice ratio is computed under the new steady-state inflation. The dotted red and blue lines correspond to the Opacity sacrifice ratio under both policies, which is equivalent to $\sigma_u \to \infty$. The vertical black dotted line is the baseline calibration, $\sigma_u = 0.2717$.

tion policies as in Figure 1 if the sacrifice ratio is the critical outcome of interest. This is due to the inability to announce a Could Turkey disinflation policy credibly. Still, it is sufficient to generate lower output costs than the Opacity case, that do not provide information from the disinflation path other than the inferred by interest rate decisions.

4 Concluding remarks

There is a long-standing debate about whether disinflations are less costly under "Cold Turkey" or gradual strategies. Central banks under inflation targeting commonly choose the latter despite the empirical evidence pointing toward faster disinflations. This paper provides a model to understand under which circumstances gradualism is beneficial under inflation targeting. The model is a standard New Keynesian model with imperfect credibility and noisy inflation target announcements.

Under full information, gradualism may be beneficial depending on the indexation scheme. But this channel is unlike to explain why central banks under inflation targeting opt to gradual policies. Gradual policies are more effective when there is imperfect credibility. When agents learn about the changes in the inflation target, gradualism allows for an inflation path closer to the target than under CT. This allows a weaker central bank reaction, leading to a milder recession.

Inflation targeting promotes more precise information about the inflation pursued by the central bank, enhancing the learning process and better anchoring the expectations during a disinflation. This decreases the sacrifice ratio. Interestingly, it also diminishes the relative gain of gradualism.

The result suggests that other determinants for the sacrifice ratio could be incorporated into future empirical studies, such as the degree of indexation and the gap between the inflation expectations and its new level after the disinflation.

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