A New Keynesian Perspective on Announcing Inflation Targets

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Abstract:

In practice inflation targeting central banks announce future inflation targets and any anticipated changes in the target. They must choose how far in advance to announce a target change and whether to make the change in single or multiple steps. This paper considers these issues in a standard New Keynesian model and finds that the optimal announcement length and the number of steps taken during transition to a new target vary consistently with the degree of price rigidity in the economy and the response of the monetary authorities to the inflation gap in the authority's policy rule.

JEL Classification: E42 - Monetary Systems; Standards; Regimes; Government and the Monetary System; Payment Systems; E52 - Monetary Policy; E58 - Central Banks and Their Policies; E61 - Policy Objectives; Policy Designs and Consistency; Policy Coordination.

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Introduction

Inflation targeting (IT) is considered desirable in part because it provides a single, clear, and observable nominal anchor for an economy, inflation. It's generally recommended as a regime for economies with low and stable inflation. Many emerging economies, however, adopted IT regimes in order to obtain low and stable inflation (Chile, the Czech Republic, Hungary, Mexico, South Korea and Thailand to name a few). These economies often started with high inflation and announced a sequence of lower targets over a finite time horizon. Coming out of the Great Recession many advanced economy central banks are announcing short and medium targets combined with lower targets in the longer run. In these environments it is no longer clear what the effective nominal anchor is since the current target differs from the target in, say, 6 months or a year. A number of other questions follow: To which target does the central bank respond to now? Is there an optimal announcement time for such changes? Should the change occur all at once or in steps? If steps, how many? How such economies behave and addressing these questions is the topic of this paper.

This paper takes what central banks do seriously and considers that they are trying to solve the optimality problem of choosing all aspects of their policy to maximize individual welfare. We do this in a standard New Keynesian (NK) model along the lines of Clarida, Gali and Gertler (1999), Woodford (2003), Gali (2008) and many others. This is the workhorse model in much of the modern academic research on the topic and in many central banks today. We include positive steady state inflation and a Taylor rule with an explicit inflation target. We calibrate the model using parameters most common in the literature. Doing so allows for our results to be relevant to the widest possible audience. To the best of our knowledge, the effects of changing the inflation target itself has never been formally investigated. This paper is aimed at remedying this as a first step toward improving our overall understanding of modern IT central banking. It is as much a comment on the implications inherent in the NK workhorse model itself as it is on IT in practice.

Expectations in a broad sense have received a lot of attention in the literature. Friedman and Kuttner (2010), Gali and Gertler (2007), Woodford (2003 and 2007) are just some of the more recent and prominent examples. Earlier Mishkin and Savastano (2001) and Bernanke, B., Laubach, T., Mishkin, F., and Posen, A., (1999) argued that inflation targeting requires transparency and sound institutions to function well. Mishkin (2004) even appealed to these institutional features in arguing that the US Fed should officially adopt IT. Woodford (2007) and Svenssen and Woodford (2005) argued that modern central banking is largely about managing expectations and focused on inflation forecast targeting in practice. Canova and Gambetti (2010) examined the role of expectations during the Great Moderation. But they focused on the expectations of individuals in the economy over future values of endogenous variables like output and inflation. Little has been discussed about expectations over the future values of exogenous variables considered key to managing inflation and output expectations, namely, future changes in the central bank's inflation target itself. The closest notion to ours appears to be in Davig and Leeper

(2007) which investigates a Markov process governing the Taylor parameter[1] in interest rate rules. They call a change in the Taylor parameter a regime switch. They consider a constant inflation target and random variation of the Taylor parameter and find that the regime changing model fits the data better than a constant-regime model.

Our focus is on taking the transparency and announcement issues seriously by considering the case of a central bank announcing a future change in its inflation target. While this is a case frequently cited in arguing for IT regimes (Mishkin, 2004, Bernanke et al, 1999, and Woodford 2007) it is actually a case that, to the best of our knowledge, has never been addressed formally. This is surprising since one of the key arguments for IT regimes is that the IT central bank would announce any changes ex ante and explain any deviations from targets ex post.

Modeling Announcements

We utilize a standard NK model with a non-zero inflation target. Within that model we consider the effects of a credible central bank announcing changes in the inflation target. Logically, the first questions one might ask about announcing any change are: when, how long, and how much. In this context, "when" refers to whether the central bank is announcing at date t a change that will occur at date $t+1$ or at date $t+10$. We refer to this as the "announcement length", the length of time between the announcement and the change occurring. "How long" then refers to how long any given change remains in effect (e.g., permanent versus temporary changes). "How much" refers to the total change in the target.

[1] By the "Taylor parameter" we mean the response of interest rates to changes in the inflation gap in a Taylor-type interest rate rule.

To facilitate comparison across experiments, we always consider the same total change in the target. We start in a steady state with 10% inflation and end in a steady state with 2% inflation. Although we aren't trying to make particular empirical statements here, this decrease is consistent with the experience of many emerging market economies that adopted IT to lower inflation. Our initial experiments focus on announcement lengths in isolation. We consider only permanent target changes and a few discrete announcement length options: 6 months, 12 months, 18 months and 24 months. While we focus on lowering inflation, an example inspired by the experience in many emerging market IT countries, the results concerning the role of announcements and various timing options are broader, speaking to the issues involved in any announced target change under IT.

As a baseline we use calibrated values at the monthly frequency that are commonly found in the literature[2]. We find that 12 months is the optimal length for such announcements. To be clear, this is the case where at date $t = 0$, the steady state inflation rate and inflation target are 10%. The central bank publicly and credibly announces that at date $t = 12$ the target will be discretely and permanently changed to 2%. This means that at date $t = 1$, individuals are living in a world where they know that the future $t \geq 12$ world has a steady state inflation rate and inflation target of 2% but the central bank is currently still pursuing a 10% target. To generate the eventual decline in inflation there is always a period during transition when consumption, and hence output in this closed economy, declines[3].

[2] All of our simulations are done mixing deterministic and stochastic shocks in Matlab using Dynare. For more on Dynare: http://www.dynare.org/ . All of our code is available upon request

[3] Ball (1994 and 1995) show that output doesn't necessarily fall with a credibly announced decrease in inflation. His analysis turns on his model where a decrease in the growth rate of money generates the decline

Although individuals are expecting a decline in the nominal interest rate across steady states, at the initial date there is a temporary increase in the real interest rate which translates into a transitory increase in the consumption growth rate. For reasonable announcement lengths[4] then there is a period of increasing and of decreasing consumption during transition to the final steady state. It is this tension between above-steady-state consumption increasing utility and below-steady-state consumption decreasing utility that determines the announcement length that is optimal in terms of maximizing the lifetime utility of individuals. The consumption boom comes early and the contraction later as the economy nears the announced date of the target decrease. Thus, the optimal announcement length maximizes the discounted utility gain from the early boom relative to the amount of time individuals must suffer the contraction. As the announcement length gets shorter, the central bank puts the economy through a severe and sudden contraction sooner to meet its more rapidly approaching lower target date. This is more painful for individuals and thus under nearly all parameterizations is a suboptimal choice for a socially benevolent central bank.

The opposite also turns out to be suboptimal. If the announcement length is long enough, then the consumption boom is delayed since the announced change is too far in advance to affect initial behavior much. In an economy with an IT central bank this means that interest rates will rise during the consumption boom. Early in the transition, individuals

(versus a decrease in the level of money). In cashless NK models this is clearly not the case since these models don't include money at all. Thus, we do not view our work as a continuation or comment on his earlier insights.

4 A short enough length of, say, one date can generate only a decline in consumption. While we don't focus on these essentially surprise changes, all our simulations were tested for robustness over a wide range of announcement lengths and parameterizations.

now expect an increase in the near term future interest rates and thus a declining consumption path. This generates a mild contraction early, a boom in intermediate dates and a deep contraction as the date of the target change nears. Eliminating this initial contraction is welfare enhancing and thus central banks do not choose the longest length either. The final result is that there is an interior optimum for the length. With our baseline calibrated values for a single target change (i.e., not lowering the target in steps) the optimal length is 12 months long. We believe these experiments get at the heart of the notion of managing expectations in the broadest, yet still very relevant sense.

We compare simulations results over a range of parameters and find that the "Taylor parameter" and the "Calvo parameter" are key to determining the optimal length. By the "Taylor parameter" we mean the response of interest rates to changes in the inflation gap in a Taylor-type interest rate rule. By the "Calvo parameter" we mean the parameter in the Calvo pricing problem determining the probability of a firm not being able to optimally update prices. In general, increasing the Taylor parameter shortens the optimal length since the boom periods, which are also temporarily inflationary, are dampened by a more rapid increase in interest rates. Increasing the Calvo parameter (i.e., more rigid prices), extends the optimal length because it takes longer for the economy to adjust. While there is a wide range of intermediate values for which 12 months is optimal, the exact length for a particular economy will depend on that economy's combination of these two parameters.

Our initial experiment is a first analytical step in exploring the effects of announcing target changes and for understanding the mechanisms at work in the NK model. We don't, however, usually observe such large adjustments announced in advance. It is more plausible, and observable in practice, that a central bank announces a sequence of changes in the target until it reaches the final, lower target. To capture this notion of reducing a target in steps in a way that is consistent with our initial experiment, we consider the same 8% total reduction in the target and the same total lengths of time: 6, 12, 18, and 24 months. Within each announcement length, we then consider 4 possible step-wise linear target paths. First we consider a one-step decrease in the target. This is our initial experiment. Second we consider a two-step decrease. Third we consider a three step decrease. Finally, we consider the discrete time limiting case of a step at each date. Since we have no theory yet for varying the length of each step, we only consider equal-length steps. Using our accepted calibrated values, we again run simulations of all the cases and rank outcomes according to utility. The final result for the particular case of the baseline model in the literature, as an example, is that it is optimal to announce a decrease in the inflation target from 10% to 2% 24 months in advance and to achieve that long-run decline with an intermediate target 12 months out that is 6%.

Our general conclusion is simply that announcements do matter. This is not new in a literature that has long argued that the modern conduct of monetary policy is as much about managing expectations as it is about specific tools and their use. What is new is that we formally look at one way in which central banks do in practice manage expectations – i.e., by announcing future targets and their changes. For commonly accepted parameter values we find that it is optimal to announce target changes 12 months in advance and that it is optimal to approach this final target through an announced sequence of steps. We also find that the exact length will differ according to an economy's specific parameterization, especially of their policy rule's reaction function and degree of price sluggishness. The resulting time paths of many key macroeconomic variables such as consumption and inflation vary along the transition path in this environment in ways that are not readily apparent from causal intuition about economies described by NK models. There is nothing unusual in our NK model and thus our results suggest an additional area for exploration of policy options within this popular class of models.

Model

Since this model is well studied at this point in the literature, we skip the detailed derivations from microeconomic foundations[5]. The only modeling change we make is to include a positive inflation target. A similar model to ours can be found in Clarida, Gali and Gertler (1999).

Since we consider positive steady state inflation and NK models are based on firms optimizing in a Calvo (1983) sticky price environment, we must make explicit assumptions about the behavior of firms that are unable in a given period to choose an optimal price. We assume that the default state for non-updating firms is to increase prices at the steady state inflation rate. This keeps the model tractable, consistent with most of the research using NK models, consistent with most of the explanatory stories about why prices are

[5] Detailed derivations from micro foundations are available in a companion mathematical appendix for this paper.

sticky (overlapping contracts, etc.), and keeps us from getting sidetracked with complicated manipulations of a pricing mechanism that is commonly used in NK research[6].

NK models are known to simplify to three key equations that determine the dynamics of the economy.

(1) $\tilde{\pi}_t = \beta E_t\{\tilde{\pi}_{t+1}\} + \kappa \tilde{y}_t$

(2) $\tilde{y}_t = -\frac{1}{\sigma}\left(i_t - E_t\{\pi_{t+1}\} - r_t^n\right) + E_t\{\tilde{y}_{t+1}\}$

(3) $i_t = \rho + \phi_\pi \tilde{\pi}_t + \phi_{\tilde{y}} \tilde{y}_t$

where, π_t is the inflation rate, β is the subjective rate of time preference for the economy's representative agent, $\tilde{\pi}_t$ is the deviation of inflation from steady state, κ is a constant parameter that is decreasing in the index of price stickiness (θ), in the measure of decreasing returns (α), and in demand elasticity (ε) but increasing in the representative agent's parameter of risk aversion (σ). y_t is output and y_t^n is the natural rate of output making $\tilde{y}_t \equiv y_t - y_t^n$ the output gap, $r_t^n \equiv \rho + \sigma E_t\{\Delta y_{t+1}^n\} = \rho + \sigma \psi_{ya}^n E_t\{\Delta a_{t+1}\}$ is the natural rate of interest[7], ρ = -log(β), and ϕ_π and $\phi_{\tilde{y}}$ are non-negative parameters chosen by the monetary authority. We refer to ϕ_π as the "Taylor parameter".

Equation one is the familiar NK Phillips curve relating inflation to expected inflation gaps and the current output gap. The second equation is the dynamic IS curve derived from the

[6] Ibid.

[7] Where $\psi_{ya}^n \equiv \frac{1+\varphi}{\sigma(1-\alpha)+\varphi+\alpha}$ and φ is the Frisch elasticity of labor supply.

Euler relation for consumption and aggregate equilibrium equating output and consumption. The last is the Taylor-rule type interest equation that an IT central bank would follow.

Since we are interested in IT regimes, we expand $\tilde{\pi}_t \equiv \pi_t - \bar{\pi}$. This raises the first issue of what defines the steady state inflation rate, $\bar{\pi}$. Throughout we'll assume full commitment and credibility for the central bank. In that case, it is clear that a stable inflation target, π^T, becomes the economy's nominal anchor and defines steady state inflation, $\pi^T = \bar{\pi}$. We can now write, $\tilde{\pi}_t \equiv \pi_t - \pi^T$.

The second issue is that announcing future target changes requires targets to differ over time. This means that steady state inflation rates differ with changes in the target. The block recursive nature of these models means that the steady state value of output remains unchanged. As a result, $\tilde{y}_t \equiv y_t - y_t^n$ does not need to be modified, but inflation deviations from steady state become: $\tilde{\pi}_t \equiv \pi_t - \pi_t^T$ and $E_t\{\tilde{\pi}_{t+1}\} \equiv E_t\{\pi_{t+1}\} - \pi_{t+1}^T$. That the future target is not preceded by the expectations operator reflects the full credibility assumption. While it is possible that $\pi_t^T = \pi_{t+1}^T$ it is no longer necessarily the case. Rather, it is an aspect of the model's parameterization that must be specifically stated.

The targets are made more explicit by writing the system as follows.

(4) $$\pi_t = \pi_t^T + \beta\left(E_t\{\pi_{t+1}\} - \pi_{t+1}^T\right) + \kappa\tilde{y}_t$$

(2) $$\tilde{y}_t = -\frac{1}{\sigma}\left(i_t - E_t\{\pi_{t+1}\} - r_t^n\right) + E_t\{\tilde{y}_{t+1}\}$$

(5) $i_t = \rho + \phi_\pi \left(\pi_t - \pi_t^T \right) + \phi_y \tilde{y}_t$.

This formulation allows one to be more precise about the assumptions over targets and policy. The standard case considered in the literature is a constant, zero-inflation target, $\pi_t^T = \pi_{t+1}^T = 0$.

To see why this is slightly different than how the literature has been addressing similar issues, consider Davig and Leeper's (2007, 2008) notion of varying the Taylor parameter. Their case is of a central bank that keeps the inflation target constant but adjusts the response of interest rates to inflation deviations from target, i.e., the Taylor parameter. That is, the central bank "fights inflation" more strongly. This change of the Taylor parameter defines a new monetary regime in their terminology. In our case, we keep the Taylor parameter constant and vary the target itself. This different inflation target defines a new monetary regime in our terminology. Davig and Leeper's new regime technically lowers the variance of inflation around steady state. A new regime in our model changes steady state inflation itself.

Equations (2), (4) and (5) make clear that the effects of changing the current target also differ from announcing a change in a future target. It now becomes more important to be clear about the length of the new regime. The next section discusses these issues at greater length. We then present simulated results that build on the above intuition, consider announcements of different lengths, different steps, and determine an optimal length based on maximizing utility.

Thought Experiments and Common Intuition

To emphasize that the current intuition about announcements needs clarification, we first consider some natural thought experiments. If the central bank lowered its inflation target, it seems straightforward that interest rates would rise to discourage current consumption, lower inflation and move the economy to the new, lower inflation steady state. The rate at which this transition occurs would depend on the degree to which the central bank fights inflation, offsets the output gap, and how fast prices are able to adjust (i.e., on the Taylor and the Calvo parameters, respectively). Announcing a future decrease in the target would be similar. Agents would adjust their contracts as they are able, inflation would begin to decline today and the rate at which this transition occurs would depend on the degree to which the central bank fights inflation, offsets the output gap, and how fast prices are able to decline. In both cases it's clear that consumption and output would decline and recover according to the dynamics of the system as the economy transitions to lower inflation.

Mathematically, standard intuitive analysis (see Gali (2008) Chap 4, pp. 77-78, for example) proceeds by considering a permanent increase in inflation. Totally differentiating (5) and (4) yields

(6) $$di = \phi_{\pi} d\pi + \phi_{\tilde{y}} d\tilde{y}$$

and

(7) $$d\pi = \beta d\pi + \kappa d\tilde{y}\,.$$

Combining these, one can show that

(8) $$di = \left[\phi_\pi + \frac{\phi_{\tilde{y}}(1-\beta)}{\kappa}\right] d\pi \qquad \Rightarrow \qquad \frac{di}{d\pi} = \left[\phi_\pi + \frac{\phi_{\tilde{y}}(1-\beta)}{\kappa}\right] > 0\,.$$

An increase in inflation this period leads to an increase in the nominal interest rate. This condition is related to Taylor determinacy. It shows that the real interest rate must eventually rise in the face of an increase in inflation, acting as a stabilizing force (Gali 2009 and Woodford 2003). This must occur because the target remains unchanged. In the standard experiment, steady state inflation remains at zero. The real interest rate must rise to slow real activity and thereby lower inflation back to its steady state level.

Since π^T enters negatively into the same expression, at first glance it would seem that an increase in the target would simply have the opposite effect of the increase in inflation discussed in equation (8). To see this, simply imagine the above derivatives were taken with respect to $\tilde{\pi} \equiv \pi - \pi^T$ instead. In the above instance, we considered a change in inflation (and constant target), hence, $d\tilde{\pi} \equiv d\pi$. Next considering changing the target instead, so let $d\tilde{\pi} \equiv -d\pi^T$ and

(9) $$di = \left[\phi_\pi + \frac{\phi_{\tilde{y}}(1-\beta)}{\kappa}\right]\left(-d\pi^T\right) \Rightarrow \qquad \frac{di}{d\pi^T} = \left[\phi_\pi + \frac{\phi_{\tilde{y}}(1-\beta)}{\kappa}\right](-1) < 0\,.$$

But this isn't correct. We can conceptually consider the long run effect of a permanent change in inflation while holding the target constant, but it is not correct to consider a permanent change in the target without a change in inflation.

Rather, totally differentiating (4) and (5) now yields

(10) $di = \varphi_\pi \left(d\pi - d\pi^T \right) + \varphi_{\tilde{y}} d\tilde{y}$

and

(11) $d\pi - d\pi^T = \beta \left(d\pi - d\pi^T \right) + \kappa d\tilde{y}$.

And,

(12) $di = \left[\phi_\pi + \frac{\phi_{\tilde{y}} (1-\beta)}{\kappa} \right] \left(d\pi - d\pi^T \right) \quad \Rightarrow \quad \frac{di}{d\pi^T} = \left[\phi_\pi + \frac{\phi_{\tilde{y}} (1-\beta)}{\kappa} \right] \left(\frac{d\pi}{d\pi^T} - 1 \right).$

One must first understand the effect of a change in the target on inflation before proceeding. In particular we must know if $\frac{d\pi}{d\pi^T} \underset{<}{\overset{>}{}} 1$before we can make further statements. Solving the system by hand becomes intractable as we extend our analysis beyond changing the current target and thus we resort to simulations.

Calibration and Simulation

Our model is calibrated so that time periods correspond to months. We have tried to keep our parameters as consistent as possible with the generally accepted values in the literature. This both avoids any confusion that our particular parameterization is driving our results and ensures our results speak to the widest number of researchers and other papers as possible since the model and parameters are widely used. Specifically, we use the same values as those found in Gali (2003) and Gali (2008). The only exception is risk aversion, σ, on consumption. We allow the the subjective rate of time preference= 0.9, since we calculate utility directly using $U\left(C_t, N_t\right) = \frac{C_t^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\varphi}}{1+\varphi}$ which is undefined at $\sigma = 1$.[8] We set the subjective rate of time preference, $\beta = 0.99$ and assume unitary Frisch elasticity of labor supply, $\varphi = 1.0$. In the interest rate rule we use $\phi_\pi = 1.5$ and $\phi_{\tilde{y}} = 0.0417$, which is 0.5 divided by 12 to calibrate for monthly simulations. Additional parameters[9] are $\alpha = 0.33$, $\theta = 0.667$, and $\varepsilon = 6$.

Policy Experiments: Announcing Target Changes

This section considers a single step reduction in the target from 10% to 2% inflation. We investigate how the announcement length affects endogenous variables and ultimately welfare. For our the calibrated values, the optimal announcement length is 12 months.

Baseline Case of a 12 Month Announcement

Graph 1 presents the mean simulated time paths for consumption (and output), inflation, the inflation target and for the nominal interest rate for the case of a 12 month announcement length. For our baseline calibration values, we find that 12 months is the optimal length for such announcements.

[Insert Graph 1]

At date *t = 0*, the steady state inflation rate and inflation target are 10% and the nominal interest rate exceeds that by the amount of the constant real interest rate which must equal

8 Since σ is the risk aversion parameter and we're focusing on evaluating different expected utility sequences, as a robustness check, we also calculate our simulations using a range of sigma values from 0.45 to 1.65. Our results are qualitatively robust to changes in σ.

9 α is the concavity of production and ε is the price elasticity of demand for Calvo-pricing firms.

the subjective rate of time preference[10] since this is a closed economy. The central bank publicly and credibly announces that at date $t = 12$ the target will be discretely and permanently changed to 2%, shown in blue in the upper right panel of Graph 1. This means that at date $t = 1$, individuals are living in a world where they know that the future $t \geq 12$ world has a steady state inflation rate and inflation target of 2% but the central bank is currently still pursuing a 10% target. Across steady states both inflation and the nominal interest rate must decline which is seen in the upper right and lower left panels in Graph 1.

The initial effect on consumption is negligible to the naked eye (consumption increases by 0.7%). By the Euler equation for consumption which is obtained using equation (2) and the equilibrium condition equating aggregate consumption with output, the consumption path is upward sloping as long as the fall in expected inflation is larger than the fall in current interest rates. To see this, totally differentiate (2) and rearrange to obtain,

$$(19) \qquad d\left(y_{t+1} - y_t\right) = \frac{1}{\sigma}\left(di_t - E_t\left\{d\pi_{t+1}\right\}\right).$$

Initially, under our baseline calibration, the mean percentage change in interest rates upon impact is + 0.172% since inflation also increases by 0.109%. But, the percentage change in inflation over the next period is – 0.06% which is the change expected upon impact. An approximation of the right-hand-side term in (19), which is the change in the effective real interest rate, is +0.172 – (– 0.06) = 0.232, implying an expected increasing path of output and consumption. Expected next period inflation is falling faster than nominal interest

[10] Technically the subjective rate of time preference is β and the term in the expression for the formula for the nominal interest rate is $\rho \equiv -\log \beta$.

rates for the mean simulation response until period 5 which is the peak consumption point in this simulation. This is the consumption boom response from announcing a future decline in the inflation target.

Throughout the initial boom period interest rates continue to fall since inflation is generally lower than the initial target which the central bank continues to follow until date $t = 12$. Since the policy rate responds more to inflation ($\phi_\pi = 1.5$) than to output ($\phi_{\tilde{y}} = 0.0417$), the interest rate declines despite the boom in output.

To generate the eventual decline in inflation so that inflation is at its final $t \geq 12$ target level, interest rates must rise severely as the $t = 12$ date nears. This generates a fall in consumption as economic activity is reigned in to fight inflation. There is a discrete change in the expected future inflation rate one date prior to the change, $t = 11$, since in the next date the new target comes into existence. We argue later that this large discrete change is not observed in practice and explore ways the central bank avoids this. In particular we focus on approaching the final, lower target by ratcheting down the target in steps during the transition period. Nevertheless, this discrete adjustment is the prediction of NK models with large, announced single step target changes.

This initial example of the baseline calibrated case opens up the mechanics behind the economic adjustment when future target changes are announced. The next question is how far in advance the central bank should announce target changes.

Welfare Ranking Announcement Lengths

Keeping the baseline case parameterization, we next simulate the economic response to announcements of four different lengths: 6, 12, 18 and 24 months. Since 12 months is optimal for this parameterization, Graph 2 presents the simulated paths for consumption for the optimal announcement length, 12 months, and for a length that is too short, 6 months, and too long, 18 months. The results for the 24 month case look similar but more exaggerated than the 18 month case and are not shown here to avoid clutter[11].

[Insert Graph 2]

The middle, solid line in Graph 2 is the path of consumption for the 12 month case (i.e., the same path as the upper left panel in Graph 1). In welfare ranking these outcomes, we calculate the present value of expected lifetime utility. Since utility is the same in all cases in the old steady state and in the final steady state, this amounts to comparing the present value of utility for the longest horizon considered, 24 months, but for all announcement lengths.

In all the simulations presented in Graph 2, there is a period of increasing and of decreasing consumption and hence utility during transition to the final steady state. The basic intuition behind the utility ranking can be seen in comparing areas between the mean consumption path and zero which represent the consumption, and hence (non-discounted) utility, gain or loss from the policy considered. For nearly identical losses under each announcement length, the best policy from a welfare perspective will be the one with the largest gain, i.e., area above zero in Graph 2. This clearly is not the gain under the 6 month announcement case. It appears largest under the 18 month path although there is an initial period of minor

[11] They are available upon request. They are also used in all our other rankings and calculations.

loss as well. When discounting is included, the optimal path turns out to be the 12 month path. While the total gain under the 18 month path may be larger, in discounted value the 12 month path maximizes the gain period. Again, optimality will depend on parameterization. We do not claim that 12 months is a universal result. It is merely the result for the standard calibrated NK model and is sufficient to show that announcements matter and the announcement length is a non-trivial decision for central bankers to make. Nevertheless, since the optimal length depends on a given economy's parameters, it is important to understand how the optimal length is influenced by the model's parameters.

Parameterization: Focus on the Taylor-Interest and Calvo-Pricing Parameters

It is the tension between above-steady-state consumption increasing utility and below-steady-state consumption decreasing utility that determines the announcement length that is optimal in terms of maximizing the lifetime utility of individuals. The two key parameters that stand out in the literature are the Taylor parameter governing the policy response of interest rates to deviations of inflation the relevant target and the Calvo pricing parameter that governs the degree of price rigidity in the economy. Without sluggish prices, there is no concern over inflation, and the Taylor parameter is obviously key for Taylor determinacy to be met in these models (see Woodford, 2003, for a detailed discussion of these issues). After running an initially coarse search over variations in the following parameters – α , θ, ε, ψ, σ, ϕ_{π} , and $\phi_{\tilde{y}}$ – we find that the Taylor parameter and Calvo pricing parameter are the key drivers in determining the optimal announcement length. We do not claim that the other parameters are irrelevant, only that the results are much more sensitive to any changes in the Taylor and Calvo parameters which is also very much in line with the general focus in the literature[12].

Graph 3 shows the result of a tighter search over just variations in the Taylor parameter and the Calvo pricing parameter. To see the effect of changing each parameter, begin with the baseline calibrated values of ϕ_{π} = 1.5 and θ = 0.667 placing one in the center of Graph 3 where a 12 month announcement length is optimal. Consider increasing the Taylor parameter from 1.5 to 1.8. There is no change. The harsher response of the central bank leaves 12 months optimal. Graph 2 helps explain why this is so. Increasing the Taylor parameter removes the above zero booms, but leaves the below zero contractions and likely makes them worse. The mild initial recession under an 18 month announcement is now made more severe. The 12 month length continues to welfare dominate the 6 month length although it's conceivable that for high values, like 1.8, there could be an intermediate length between 6 and 12 months that becomes optimal. Nevertheless, for our discrete choices, 12 months remains optimal.

[Insert Graph 3]

Decreasing the response in Graph 3 from 1.5 to 1.2, however, changes the optimal announcement length from 12 to 18 and then to 24 months. Again, Graph 2 shows why. Lowering the Taylor parameter now makes the initial recession of the 18 month length less and even allows it to become a boom as the central bank response gets increasingly lax,

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[12] The results of the more coarse search are available upon request from the authors. In summary, the degree of risk aversion, σ, and concavity of production, α, had very little effect except for extreme values. The Frisch elasticity parameter, φ relative to risk aversion, σ, mattered for signing utility since consumption enters positively but labor enters negatively but had little effect on our general results. It was more of a shift from ranking positive utility to ranking negative utility with little qualitative changes. Finally, the response of the policy rate to the output gap, $\phi_{\tilde{y}}$, also mattered at extreme values, but had little impact for more subtle changes.

thus lengthening the total boom period. For a lax enough response, 1.3 and lower, 24 months becomes optimal since this maximizes the boom period and pushes the costly period out the farthest.

Changes in the Calvo parameter are more challenging. For variations around 0.667 in Graph 3, everything seems clear. Starting at (0.667, 1.5) and increasing rigidity, θ, moves to a longer horizon, from 12 to 18 months. This is appealing in that one expects that the more slowly adjusting economy needs a longer time to adjust to the expected change and hence benefits from having a longer announcement length. This continues until we reach 24 months as optimal. And, this is consistent for all Taylor values from 1.4 to 1.8. Increasing θ from 0.667 raises the utility benefits of having a longer adjustment period.

The problem is that the 24 month optimal range is u-shaped in Graph 3. The story for the Taylor parameter is generally consistent, but lowering the Calvo parameter can also imply a shift to longer announcement lengths and dramatically so. Consider starting at (0.667, 1.5) and lowering the Calvo parameter a little. Doing so jumps from 12 months being optimal to 24 months. Once the Calvo parameter gets low enough, 24 months is always optimal.

[Insert Graph 4]

Graph 4 helps makes sense of this seemingly anomalous result by presenting mean results for the simulations when the Calvo parameter is restricted to 0.4 (the lower boundary in Graph 3) and we allow the Taylor parameter to be at its lower, 1.2, and upper, 1.8, boundary values. For all these combinations we find 24 months to be the optimal announcement length as seen in Graph 3. First, the relationship between these two parameters in welfare space is nonlinear. The dynamics of the system change quite a bit for more extreme values. Second, for an economy with relatively little price rigidity, the response to the announced change need not begin as early since changing later is easy to do. In Graph 4 it is clear that the initial response of consumption is less than it was compared to the baseline case. Likewise, for the Taylor = 1.2 case, consumption begins to rise initially, inflation is slow to fall since the policy rule isn't responding as strongly and the economy can enjoy a longer, albeit smaller, boom. When the Taylor parameter is 1.8, inflation falls faster as we would expect and the consumption boom is postponed until later, but due to the more flexible environment, the contraction is less severe than in the baseline case[13]. Thus, while the 24 month optimality seems surprising, it is only because the relationship is not linear and the overall dynamics of each path have changed enough.

Finally, consider the results for the opposite extreme in Graph 3 of high rigidity ($\theta = 0.9$) and a high and a low Taylor parameter (1.2 and 1.8). Again, Graph 3 shows that 24 months is always optimal. Graph 5 presents the relevant simulated paths. Now, the price adjustment in the economy is relatively rigid. To make the necessary changes given an announcement, the economy must begin to react early. This is seen in the upper left panel of Graph 5. For both a high and a low Taylor parameter, consumption changes dramatically more than under the baseline case. As more rigid prices would suggest, the inflation rate changes by much less than in Graph 4.

[Insert Graph 5]

[13] It is not clear to the naked eye. This statement is based on the actual mean consumption values.

In a broader sense, the results in Graphs 4 and 5 simply indicate a classic result in macroeconomics. When prices are free to adjust, the real economy needs to adjust less (Graph 4). When prices are more rigid, the real economy needs to make more of the adjustment (Graph 5). Combining this simple intuition with a Taylor rule that fights inflation and output gaps can lead to a wide range of time paths during transition.

Our purpose is not to explain every case. Rather, our point is made simply by showing that announcements matter, the length of the announcement depends on some well known key parameters and that the choice of the length is non-trivial. Since these are the results in a standard NK model, they imply that these are relevant policy questions in much of the modern macro literature and for central banks that apply versions of this NK model as their workhorse for analysis. Since we don't observe these dramatic discrete changes in practice, we next turn to ways within the announcement framework in which the central bank might mitigate these extreme results. In particular we consider the case where the central bank can approach the final target through a serious of steps that ratchet down the target over time.

Optimal Steps and Announcement Lengths

The previous section considered lowering the target in one fell swoop. While this does happen in practice (e.g., South Korea in 1998), it is less common. In practice central banks tend to lower their inflation targets more slowly over time (e.g., Mexico from 199 to 2003) to take full advantage of the transparency and target announcement institutional requirements of inflation targeting regimes. Likewise, during "the Great Recession", most developed-economy central bank chairs have been careful to announce medium and longer-run targets for the post-recession period. Given our results, this is also a policy that minimizes the large discrete change in the policy and allows the economy to adjust more smoothly to the new, lower target.

To explore the optimality of steps we consider our same fixed announcement lengths of 6, 12, 18, and 24 months. Within each announcement length, we consider 4 possible step-wise linear paths for the inflation target. First we consider a one-step decrease in the target. This is our initial experiment discussed in the previous sections. Second we consider a two-step decrease. Third we consider a three step decrease. Finally, we consider the limiting case in discrete time of a step at each date. Since we have no theory yet for varying the length of each step, we only consider steps that divide the total time horizon equally. Using our accepted calibrated values, we again run simulations of all the cases and rank outcomes according to utility.

[Insert Graph 6]

Graph 6 presents the time paths of the relevant variables for the case of a 12 month announcement length under all the step combinations we consider. The upper right hand panel shows the inflation targets. The most striking result here is that the limiting case looks like a smooth approach to the final target. This smooth approach manifests itself in all the other paths as well. In particular it is clear with consumption in the upper left panel that this smooth target path minimizes the variance of consumption during transition[14]. Inflation also follows a path that is intuitively appealing. After the announcement of a lower future target by the credible central bank, inflation falls consistently until the new,

[14] Since the announcement can generate a boom in addition to a contraction, it's not clear that minimizing variance is equivalent to maximizing utility, however.

lower target is achieved. It is important to keep in mind, however, that the lax statement of the previous sentence is technically incorrect. Actually, this inflationary path is the result of the credible central bank announcing a *sequence* of lower targets.

To understand the key determinants of the optimal policy, we search for Taylor and Calvo parameter combinations to all step combinations and all announcement lengths. For a fixed announcement length we simulate the model for all parameter combinations from 1.1 to 1.9 for the Taylor parameter and 0.3 to 0.9 for the Calvo parameter. In each case we run a separate simulation for each target path (i.e., step structure). Finally, we calculate lifetime utility for each simulation and rank the outcomes by utility. Graph 7 presents these results by announcement length. The vertical axes are the Taylor parameter and the horizontal axes are the Calvo parameter values.

[Insert Graph 7]

For the 6 month announcement length, the upper left panel of Graph 7 shows that only two options are ever selected as optimal: continuous steps or a single step. In general, the more rigid the economy (high Calvo parameter) and the more lax is the monetary response to inflation (low Taylor parameter), the more we find continuous steps to be optimal. This result changes as we extend the announcement length. The upper right panel of Graph 7 shows a similar result for 12 months but with a much smaller region where continuous steps are optimal. Graph 9 for an 18 month horizon, however, shows that a region where 2 steps is optimal emerges for relatively high Taylor values and low Calvo values. This is a region characterized by less rigid prices but a stricter monetary response to inflation. When we get to the 24 month horizon, Graph 10, a region where three steps is optimal also appears, again in the upper left.

The last section showed that the announcement length in a non-trivial policy choice for monetary authorities and the optimal length will vary with changes in the economy's Taylor and Calvo parameters. This section shows in Graphs 7 – 11 how, for a given announcement length, the announced target change implemented is also non-trivial and how optimality varies with two key parameters. The relationships are not linear but they do appear to be stable and consistent. As the announcement length grows, the economy has more time to adjust. Perhaps the most surprising result is that the region where the continuous step policy is optimal doesn't grow, but shrinks. Nevertheless other step regions do grow. If the objective of the central bank were to minimize variances, then it's likely that the continuous target adjustment would be optimal for a wider range of parameter combinations. But in evaluating policies here, minimizing the variance does not lead to maximizing utility as in the case of stochastic shocks around a constant steady state. Here the "shock" is in one direction, a decline in the inflation target. Returning to Graph 6, in the 12 month example, the consumption path associated with the continuous target change (upper left panel) has minimized variance but consumption is below its steady state level for the entire transition period. It's not readily apparent for which path the discounted utility-valued sum of the deviations of consumption from steady state is highest. Hence, there is no reason inherent in this model to lead one to suppose that continuous target adjustment would be optimal. And, indeed, we see in Graphs 7-11, that it isn't always optimal.

As the horizon length grows, there is more time for the central bank to allow the economy to oscillate between booms and busts to maximize individual welfare. At the shortest horizon, 6 months, there is less potential gain from parsing the transition time period and thus intermediate step combinations do not appear optimal for any parameter combination. As the horizon expands, we have to get to an 18 month announcement for there to be enough time during transition for the economy to benefit from introducing steps that break the transition period into shorter periods. Finally, at 24, there is enough transition time that the full range of step options become optimal depending on the economy's parameterization.

Our baseline parameterization and use of the NK model is chosen to speak to the largest audience since this is used widely in the literature and in practice. It is worth asking what steps would be optimal for this case since this result would be the implication for a very wide range of research. Graph 7 shows that the (1.5, 0.667) combination implies it is optimal for a central bank making a 6 months ahead announcement to use a continuous sequence of steps. If the bank uses a 12 or 18 month announcement, upper right and lower left panels, respectively, show that it would be optimal instead to use a single step. Extending the length to 24 months would instead require a benevolent bank to lower the target in two steps to maximize welfare as seen in lower right panel of Graph 7.

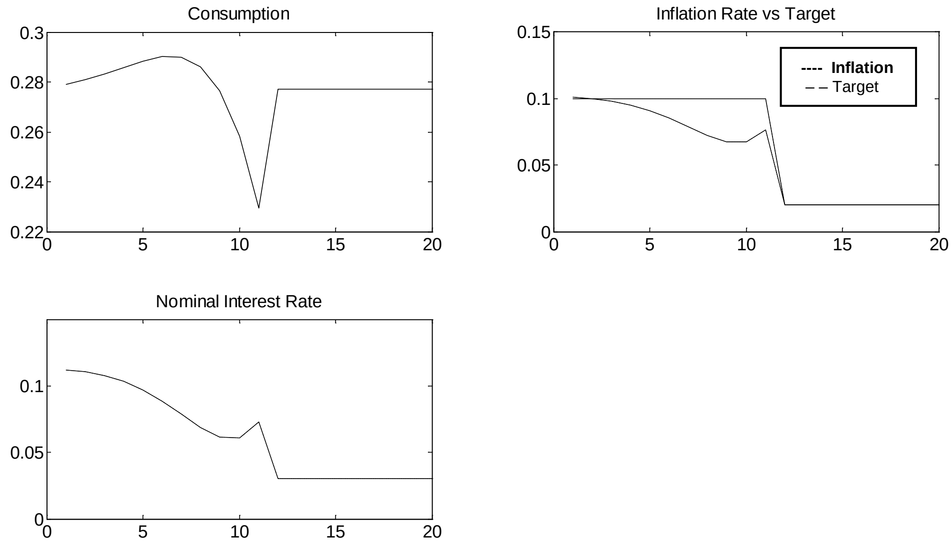
Finally, choosing between all of these options, we find that globally the highest utility is obtained from a 24 month announcement and a two step lowering of the target. And, the ranking of announcement lengths is in order of length where 6 is worst, 12 next, 18 next and so on. This is broadly consistent with the notion that inflation targeting central banks manage economic activities and anchor expectations by announcing their intentions well in advance. Using two steps allows some gain from the consumption boom relative to the continuous target path case but lessens the contraction relative to the single step case. Again, this is broadly consistent with the common practice of central banks pursuing long term and medium term targets, but not actually announcing per-month targets (our continuous case).

Conclusions

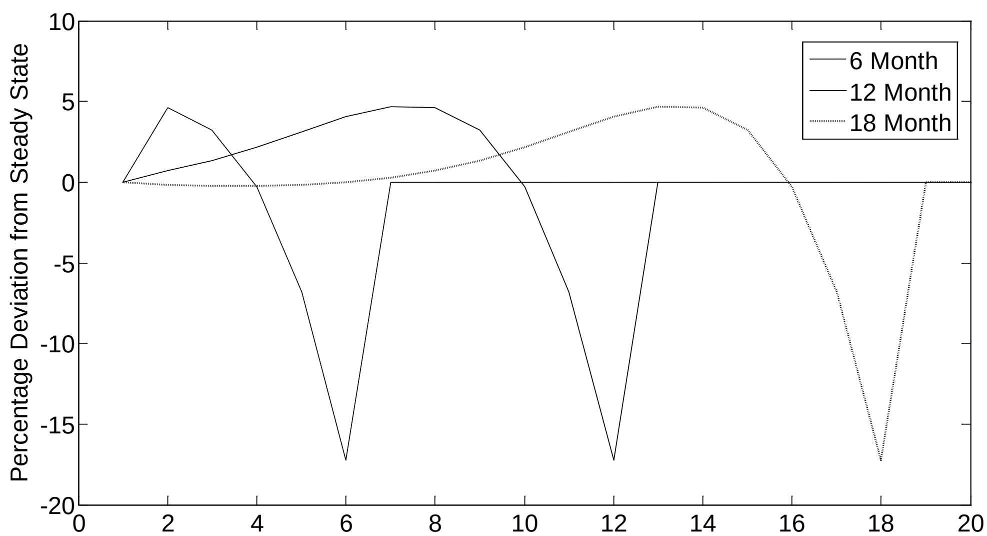
Inflation targeting (IT) is considered desirable in part because it provides a single, clear, and observable nominal anchor for an economy, inflation. But that's not how it is always implemented in practice. Central banks sometimes announce future inflation target changes. In some cases targets are ratcheted downward over time as an economy attempts to lower inflation. In other cases targets are ratcheted upward in recognition of an upcoming "loose monetary" period. This raises a number of questions such as which target does the central bank respond to now, what the optimal announcement length is and on what parameters that depends, to name a few.

The focus of this paper is on taking the transparency and announcement issues seriously by considering the case of a central bank announcing a future change in its inflation target. By formalizing the concept of announcements we make them defined objects with explicit parameters that can be analyzed in modern monetary models. We utilize a standard NK model with a non-zero inflation target and compare simulations results over a range of parameters. Our general conclusion is simply that announcements do matter. While this is not new in a literature that has long argued that the modern conduct of monetary policy is as much about managing expectations as it is about specific tools and their use. What is new is that we address how central banks operationalize their targets by managing expectations through the announcement of future targets and future target changes. For commonly accepted parameter values we find that it is optimal to announce target changes 12 months in advance and that it is optimal to approach this final target through an announced sequence of steps. We also find that the exact length will differ according to an economy's specific parameterization, especially of their policy rule's reaction function and degree of price sluggishness. The resulting time paths of many key macroeconomic variables vary along the transition path in this environment in ways that are not readily apparent from causal intuition about economies described by NK models.

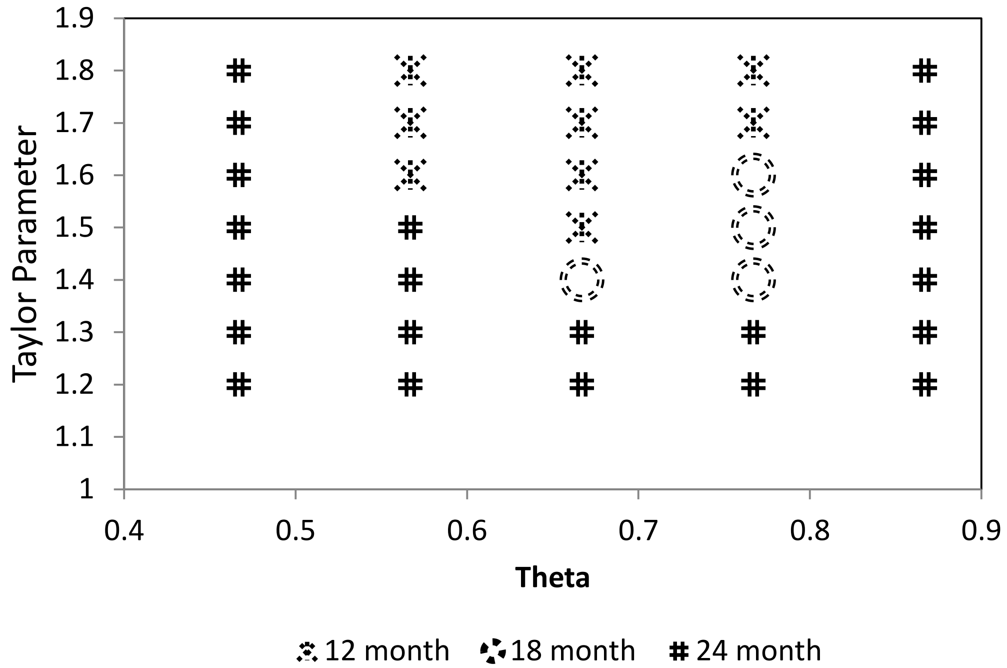
Graph1: Simulation Results for 12 month announcement



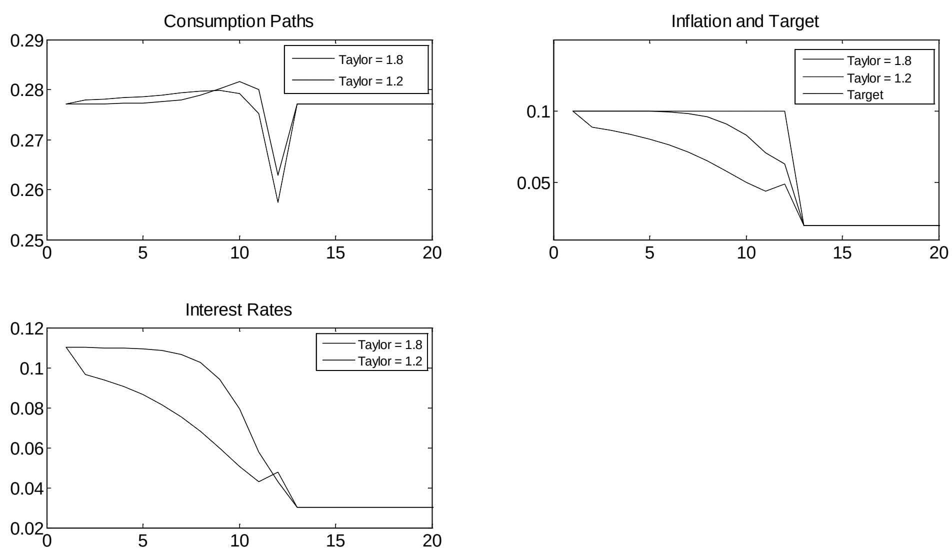
Graph 2: Consumption (and Output) Percentage Deviation from Steady State for 6, 12, and 18 Month Announcements



Graph 3: Interaction between Taylor Rule and Calvo Pricing Parameters

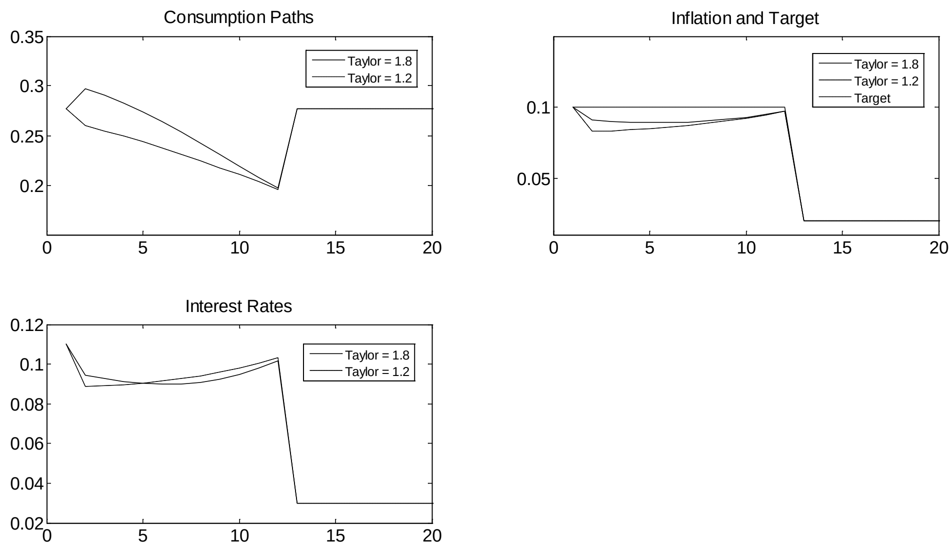


Graph 4: Low Calvo, high/low Taylor parameters for 12 Month Announcement Length



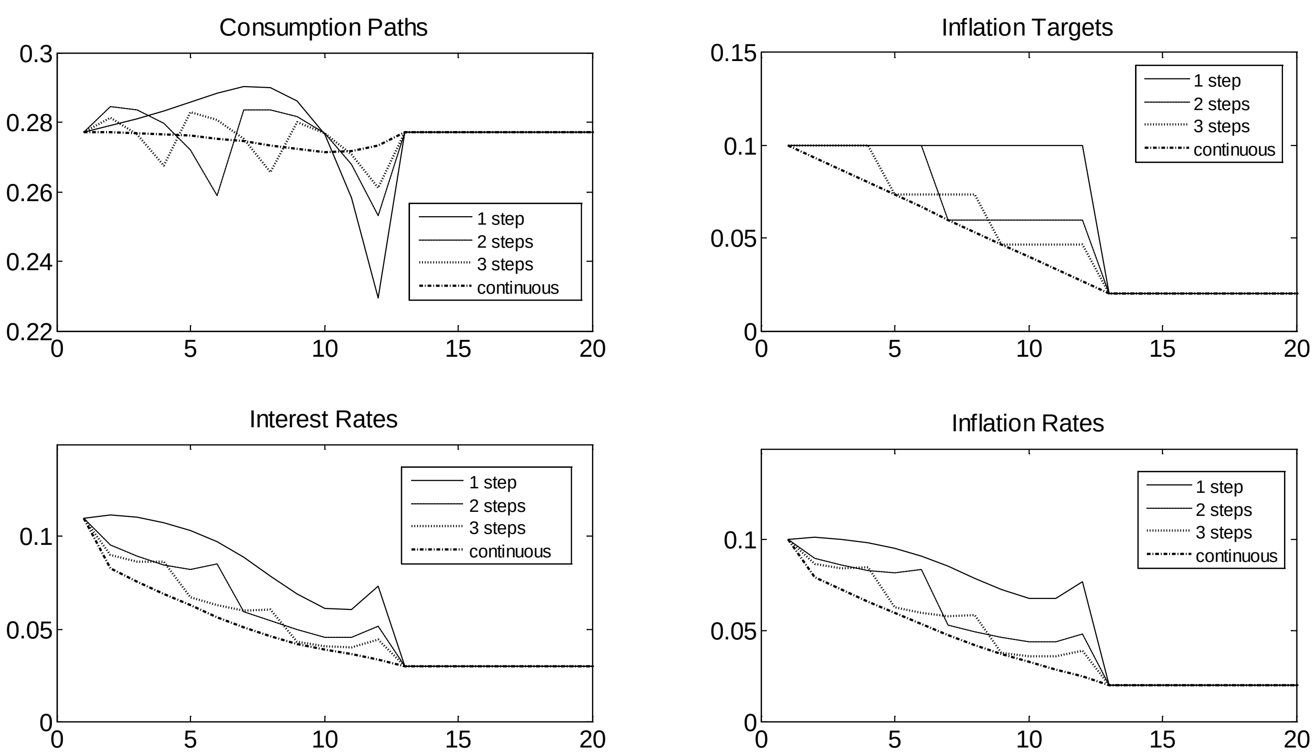
Note: This simulation has all the same calibrated values as our baseline case, but the Calvo parameter has been set very low at θ = 0.4 and we've allowed the Taylor parameter for be its lowest that we consider, 1.2, and the highest, 1.8.

Graph 5: High Calvo, high/low Taylor parameters for 12 Month Announcement Length

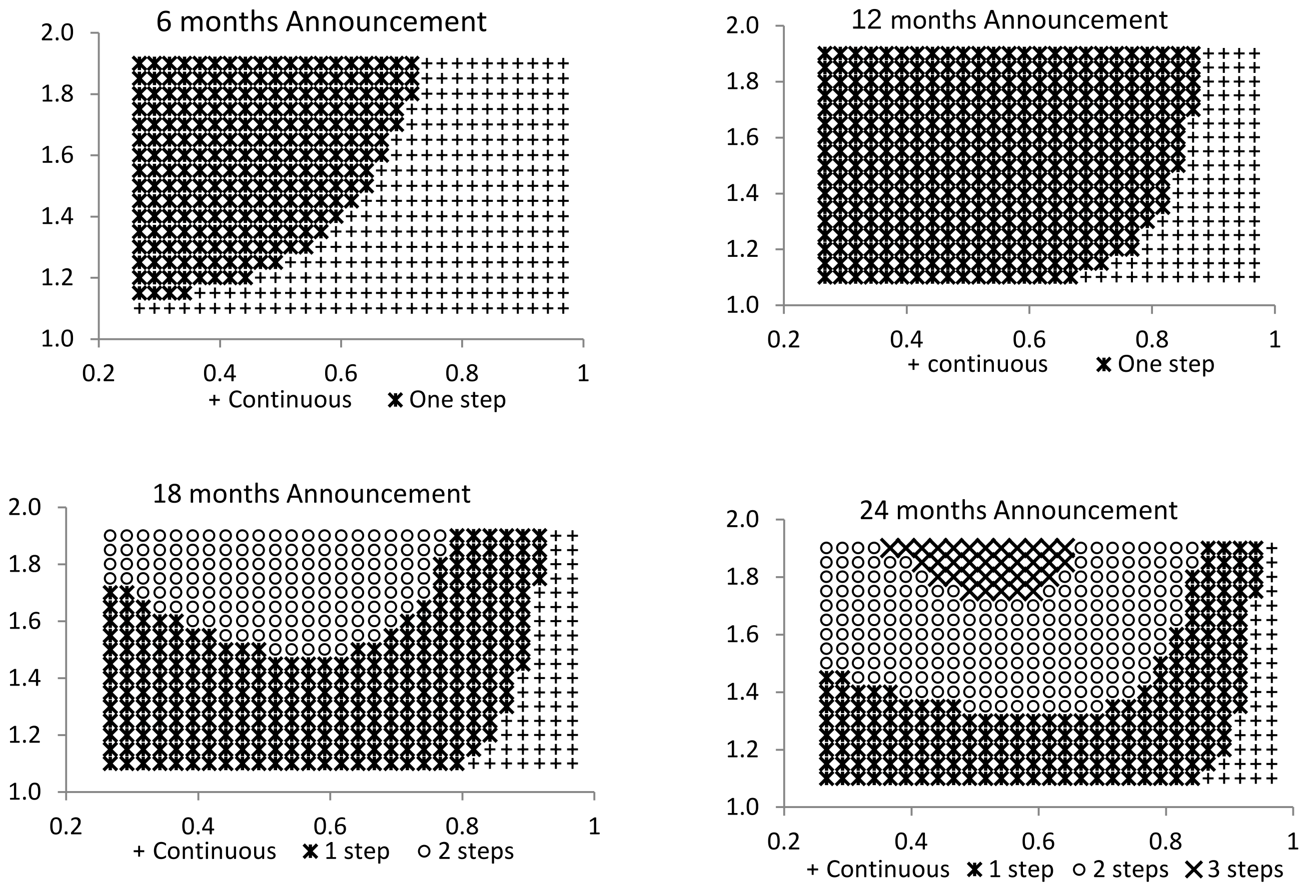


Note: This simulation has all the same calibrated values as our baseline case, but the Calvo parameter has been set very high at $\theta = 0.9$ and we've allowed the Taylor parameter for be its lowest that we consider, 1.2, and the highest, 1.8.

Graph 6: 12 Month Announcement with All Step Combinations



Graph 7: Step Combinations for Different Announcement Lengths
Taylor Rule and Calvo Pricing Parameters



Appendix

Steady State Values

	Initial Steady State	Final Steady State
Inflation Target	0.1	0.02
Inflation Rate	0.1	0.02
Nominal Interest Rate	0.11005	0.0300503
Natural Rate of Real Interest	0.0100503	0.0100503
Consumption (= output)	0.277124	0.277124
Labor	0.413617	0.413617
Natural Level of Output	0.277124	0.277124

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