Inflationary Sentiments and Monetary Policy Communication

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Abstract

We develop a DSGE model in which the conduct of monetary policy influences agents' inflationary sentiments, defined as waves of pessimism about how aggressively the central bank will react to inflation in the future. Monetary policy alternates periods of active inflation stabilization (i.e., active regime) and periods during which the emphasis is mainly on output stabilization (i.e., passive regime). Deviations from the active regime can be long or short lasting. When observing passive monetary policy, agents do not know the nature of the deviation and have to learn which type of passive regime is in place. As the central bank deviates from the active monetary policy for a longer and longer period, inflationary sentiments progressively spread among agents, who get increasingly convinced that the central bank might have switched to the long-lasting passive regime. Mounting inflationary sentiments have the effect to make the inflation-output gap trade-off worse and to depress private sector's welfare. When the model is calibrated to U.S. data, we find that inflationary sentiments sluggishly rise as the Federal Reserve deviates from active monetary policy. Such a dynamic for sentiments implies that (*i*) inflation drifts up for several years in response to a cost-push shock and (*ii*) the Federal Reserve has a large leeway in accommodating this type of shocks. Increasing the transparency of the Federal Reserve is found to improve welfare by anchoring inflationary sentiments. Gains from transparency are even more sizeable in periods when the persistence of shocks is high and for countries whose central bank has failed establishing a strong commitment to keeping inflation under control.

Keywords: Bayesian learning, constrained discretion, transparency, accountability, sentiments, inflation expectations, Markov-switching models.

JEL classification: D83, E52, C63.

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1 Introduction

The last two decades have witnessed two major breakthroughs in the practice of central banking worldwide. First, most central banks have adopted a monetary policy framework that Bernanke and Mishkin (1997) have termed *constrained discretion*. Bernanke (2003) writes that "Under constrained discretion, the central bank is free to do its best to stabilize output and employment in the face of short-run disturbances[...]. However, a critical proviso is that, in conducting stabilization policy, the central bank must also maintain a strong commitment to keeping inflation–and, hence, public expectations of inflation–firmly under control." Second, many countries have taken remarkable steps to make their central bank more transparent (Bernanke et al., 1999 and Mishkin 2001). Given the widespread endorsement of constrained discretion and transparency, two questions lie at the heart of the modern monetary policy making. First, for how long can a central bank de-emphasize inflation stabilization before the private sector starts questioning the credibility of the commitment to keeping inflation under control? Second, does transparency play an essential role for effective monetary policy making?

To quantitatively address these two important questions, the paper develops a New Keynesian Dynamic Stochastic General Equilibrium (DSGE) model in which monetary policy alternates periods of active inflation stabilization (i.e., active regime) and periods during which the emphasis is mainly on output stabilization (i.e., passive regime). While the active regime is fully revealing, when agents observe passive monetary policy, they do not know the likely duration of such a policy. In other words, agents can tell that the conduct of monetary policy is currently passive, but they are not sure about what this implies for the future: Will the central bank quickly go back to the active regime or a long period of passive monetary policy lies ahead as it occurred in the 1970s? Given that the behavior of the monetary authority is unchanged across the two passive regimes, the only way for agents to learn the truth consists in keeping track of the number of consecutive deviations. As agents observe more and more realizations of the passive regime, they become more and more convinced of being in the long-lasting passive regime and increasingly expect that passive monetary policy will prevail in the future. Thus the more the central bank deviates from active inflation stabilization, the more agents become pessimistic about a quick return to the active regime. We call this form of pessimism inflationary sentiments because the mounting pessimism turns out to gradually make the inflation-output gap trade-off worse. The ability of generating waves of pessimism in response to central bank's actions makes the model an ideal laboratory to study the macroeconomic and welfare implications of constrained discretion.

The evolution of private sector's pessimism in response to central bank's deviations from inflation stabilization influences the dynamic of welfare. In the model, welfare is a function of agents' uncertainty about future inflation and output gap. We measure uncertainty computing the conditional variance of the endogenous variables at different horizons taking into account agents' beliefs about the evolution of monetary policy. As long as the number of deviations from the active regime is low, the increase in uncertainty is very modest and in line with the levels implied by the active regime. This is because the long-lasting regime occurs quite rarely and it takes time for agents to get convinced that such a regime is in fact in place. However, as the number of deviations increases and agents from fairly optimistic become fairly pessimistic, uncertainty increases rapidly and converges to the values implied by the long-lasting regime. For each horizon, our measure of uncertainty is now higher than the ergodic long run volatility of the model. This establishes an important result: Deviations from the active regime that last only few periods have not disruptive consequences on welfare because they do not have a large impact on agents' expectations regarding future monetary policy. Instead, if a central bank deviates for a prolonged period of time, a specific form of disanchoring of agents' expectations could occur: An increase in uncertainty of agents' expectations. Such a disanchoring is associated with sizeable welfare losses.

How quickly inflation expectations and uncertainty take off depends on the central bank's commitment to avoiding long-lasting passive policy. If the commitment is weak, agents will interpret the first observed deviation as a switch to the long-lasting regime which will be accompanied by a strong and sudden rise of pessimism about observing active policies in the near future. Thus, the weaker the central bank's commitment, the quicker the deterioration of the inflation-output gap trade-off and welfare.

The aforementioned results suggest that the actual central bank's leeway in de-emphasizing inflation stabilization might be rather limited, especially for those central banks that have failed establishing a strong commitment. Nonetheless, the paper shows that increasing transparency allows the central bank to sustain longer deviations from inflation stabilization. A transparent central bank announces the monetary policy course (i.e., the planned deviations) beforehand. Transparency has a twofold effect on welfare. First, transparency reduces welfare in the short run because agents have been told that the passive monetary regime will prevail for a while. It follows that, over the early periods, uncertainty is higher than when agents are not informed about the deviations and are trying to learn about their persistence. Second, as time goes by, under transparency, agents know that the prolonged period of passive monetary policy is coming to an end. This leads to a reduction in the level of uncertainty at every horizon with an associated improvement in welfare. Notice, that this is exactly the opposite of what occurs when no announcement is made: Agents, in this case, become more and more discouraged about the possibility of moving to the active regime and uncertainty increases. Thus, as long as central bank's announcements are deemed to be credible by agents, transparency pegs the pessimism down, preventing a quick deterioration of welfare as the discretionary policy is implemented.

When the model is calibrated to the U.S. data, we find that the pessimism and hence inflation expectations change very sluggishly as more and more unannounced deviations from active policy are observed. In fact, inflation expectations and inflation -after an initial adjustment- are found to move very slowly during the first two years following a cost-push shock. If monetary policy remains accommodative after the first two years following the shock, inflation expectations and inflation rapidly accelerate and double their value within the next three years. This finding has two important implications. First, if the central bank is not transparent, the model predicts that inflation drifts up for several years after a cost-push shock, resembling the dynamic of inflation in the 1970s. Second, the Federal Reserve has large flexibility in responding to inflationary shocks even though she does not communicate her planned policy course to markets.

Although this result suggests that the Federal Reserve can successfully implement constrained discretion even without transparency, the model predicts that increasing transparency would improve welfare. The way in which transparency is modeled closely resembles the *forward guidance* about the future path of interest rate policy, which the Federal Reserve has recently decided to re-introduce. The paper shows that the *forward guidance* improves welfare especially when the monetary policy has to cope with highly persistent shocks, such as the ones that have originated the current financial crisis.

Since transparency has the effect of anchoring inflationary sentiments, gains from transparency are sizeable when cost-push shocks are highly persistent. In fact, transparency may end up depressing welfare if shocks have too low persistence. Furthermore, transparency is particularly desirable for those central banks that cannot prevent sentiments from quickly taking off, since they have failed establishing a strong commitment. This prediction of the model provides an explanation for why since 1990, many countries (e.g., Chile, Brazil, and Poland) whose central banks could not develop a strong commitment, have reformed their monetary policy strategy with the goal of rising transparency (Bernanke et al., 1999 and Mishkin 2001).[1]

This paper is related to Angeletos and La'O (2011) who develop a model in which shocks to sentiments trigger business cycle fluctuations. In Angeletos and La'O (2011), sentiment shocks are shock to average second-order beliefs (i.e., what agents believe that other agents

[1] More specifically, those countries among many others (e.g., New Zealand) have adopted a monetary policy framework that goes under the name of *inflation targeting*. The *inflation targeting* can be regarded as a kind of constrained discretion in which transparency and accountability are greatly emphasized (Bernanke, 2003).

believe about economic outcomes on average). In contrast, our model features dynamic inflationary sentiments, which capture changes in agents' pessimistic beliefs due to *observed* monetary policy actions.

This paper is also linked to papers that study how inflation's expectations respond to monetary-policy decisions, such as Nimark (2008), Mankiw, Reis, and Wolfers (2004), Del Negro and Eusepi (2010), and Melosi (2011). The latter papers conduct an econometric investigation of the issue. Eusepi and Preston (2010) study monetary policy communication in a model where agents face uncertainty about the value of model parameters. Unlike Eusepi and Preston (2010), agents in our model are not bounded rational; they have only incomplete information about the persistence of realized passive monetary regimes. In their paper, furthermore, there is no role for inflationary sentiments. Focusing on sentiments allows us to shed light on a novel type of short-run disanchoring of expectations, which differs from the one based on the asymptotic convergence of to model's predictions under rational expectations. Cogley, Matthes, and Sbordone (2011) address the problem of a newly-appointed central bank governor who inherits a high average inflation rate from the past and wants to disinflate. In the model, agents conduct Bayesian learning over the coefficients that characterize the conduct of monetary policy. The paper characterizes an optimal Taylor-type rule and study how learning affects the choice of policy.

The paper relies on methods for solving model with incomplete information and regime changes developed in Bianchi and Melosi (2011). These methods are based on the idea of expanding the number of regimes to take into account the learning mechanism and can be easily used with any of the methods developed for solving Markov-switching models, such as Davig and Leeper (2007), Farmer, Waggoner, and Zha (2009), Cho and Moreno (2011), and Foerster, Rubio-Ramirez, Waggoner, and Zha (2011). The paper is then related to a growing literature that models parameter instability to capture changes in the evolution of the macroeconomy. This consists of two branches: Schorfheide (2005), Justiniano and Primiceri (2008), Bianchi (2010a), Davig and Doh (2008), and Fernández-Villaverde and Rubio-Ramírez (2008) introduce parameter instability in dynamic equilibrium models, while Sims and Zha (2006), Primiceri (2005), Cogley and Sargent (2005) work with structural VARs.

This paper is organized as follows: Section 2 introduces the model. In Section 3, the paper calibrates the model to the U.S. economy and study the welfare implication of constrained discretion and transparency. Section 4 studies the macroeconomic effects of discretionary policies in the case in which these policies are backed up by transparency and in the case in which they are not. Section 5 concludes.

2 The Model Setup

Consider the three-equation New-Keynesian model[2]

$$\begin{aligned} y_t &= \mathbb{E}\left(y_{t+1}|\mathcal{F}_t\right) - \sigma^{-1}\left[i_t - \mathbb{E}_t\left(\pi_{t+1}|\mathcal{F}_t\right)\right] + u_t^d & (1) \\ \pi_t &= \beta\mathbb{E}_t\left(\pi_{t+1}|\mathcal{F}_t\right) + \kappa y_t + u_t^s & (2) \\ i_t &= \phi_\pi\left(s_t\right)\pi_t + \phi_y\left(s_t\right)y_t & (3) \end{aligned}$$

where $u_t^i = \rho_i u_{t-1}^i + \sigma_i \varepsilon_t^i$ with $\varepsilon_t^i \backsim \mathcal{N}(0,1)$ and for $i \in \{d, s\}$. The variable s_t characterizes the monetary regimes, which affect the inflation and output gap coefficients (i.e., ϕ_π and ϕ_y) of the central bank's reaction function (3), and $\mathcal{F}_t$ is the information set of the forward-looking agents (i.e., households and firms). The endogenous variables are the (welfare-relevant) output gap, y_t, inflation π_t, and the nominal interest rate i_t. It is assumed that agents observe the history of the endogenous variables as well as the history of the structural shocks (i.e., ε_t), that is, $\mathcal{F}_t \equiv \{y_j, \pi_j, i_j, \varepsilon_j\}_{j=1}^t$. Agents do not directly observe the history of regimes, but they need to infer their evolution to form expectations about future realizations of forward-looking variables (i.e., output gap y_t and inflation π_t). Monetary policy changes are modeled as a three-regime Markov switching process. In equilibrium, these regimes reflect how agents *a-prioristically* believe[3] that monetary policy is conducted over time. The following two features characterize the process driving the evolution of monetary regimes and the *a-priori* beliefs thereof.

We model monetary policy by introducing a Markov-switching process s_t with three monetary policy regimes that evolve according to the matrix:

$$\mathcal{P} = \begin{bmatrix} p_{11} & p_{12} & p_{13} \\ 1-p_{22} & p_{22} & 0 \\ 1-p_{33} & 0 & p_{33} \end{bmatrix} \tag{4}$$

The realized regime determines the monetary policy parameters of the central bank's reaction

[2] The derivations of the model with fixed coefficients is standrad and hence omitted. For a detailed derivations see Gali (2008), ch. 5. See also Woodford (2003).

[3] In the model, agents conduct Bayesian learning over the history of realized regimes. In order for the learning problem to be correctly specified from a mathematical point of view, we need to provide a model describing the evolution of monetary policy perceived by agents. This model is called a-priori as it not conditional on having observed any shock, endogenous variable, and monetary policy actions.

function. In symbols, for $i \in \{1,2,3\}$:

$$\left(\phi_\pi\left(s_t = i\right), \phi_y\left(s_t = i\right)\right) = \begin{bmatrix} \left(\phi_\pi^A, \phi_y^A\right), \text{ if } i = 1 \\ \left(\phi_\pi^P, \phi_y^P\right), \text{ if } i = 2 \\ \left(\phi_\pi^P, \phi_y^P\right), \text{ if } i = 3 \end{bmatrix} \tag{5}$$

Under the regime 1 (henceforth, the active regime), the central bank's main goal is to stabilize inflation (i.e., $\phi_\pi\left(s_t = 1\right) = \phi_\pi^A \geq 1$). Under the regime 2 (henceforth, the short-lasting passive regime), the central bank de-emphasizes inflation stabilization inflation (i.e., $\phi_\pi\left(s_t = 2\right) = \phi_\pi^P < \phi_\pi^A$) but only for very short periods. The regime 3 (henceforth, long-lasting passive regime) characterizes an approach to monetary policy that de-emphasizes inflation stabilization (i.e., $\phi_\pi\left(s_t = 3\right) = \phi_\pi^P < \phi_\pi^A$) for fairly long periods. It is important to notice that the passive regimes do not differ in terms of the response to inflation ϕ_π^P.

This way of modeling monetary policy allows us to study two alternative approaches to monetary policy that the empirical literature has found to govern the U.S. monetary policy from the 1960s on. The first approach is the so-called *constrained discretion* (Bernanke and Mishkin, 1997), which has characterized the U.S. monetary policy from the 1980s on. Under this approach the central bank is mainly focused on stabilizing inflation and inflation expectations but sometimes she conducts short-lasting discretionary policies[4] that de-emphasize inflation stabilization in favor of alternative objectives, such as output-gap stabilization. Under the second approach, the central bank de-emphasize inflation stabilization for very long periods. The second approach has mainly characterized the U.S. monetary policy in the late 1960s and in the 1970s.

The probabilities p_{11}, p_{12}, p_{22} govern the evolution of the monetary policy when the central bank follows constrained discretion. The larger p_{12} vis-a-vis to p_{11}, the more frequent short-lasting deviations. The larger p_{22}, the more persistent the short-lasting deviations. The probability p_{13} sets how likely it is to observe a switch from the active regime to the long-lasting passive regime. Since, under the regime 3, the central bank endorses higher inflation similarly to what happened in the 1970s, the probability p_{13} can be seen as a function of the the central bank commitment to stabilizing inflation. The probability p_{33} reflects the average persistent of long-lasting deviations. The following restrictions are consistent with the definition of the three regimes:

A1 $p_{22} < p_{33}$, implying that the regime 3 is more persistent than regime 2.

A2 $p_{12} \geq p_{13}$, implying that switches from the active regime to the short-lasting passive are expected to be relatively common.

[4] The paper will use the terms passive policy and discretionary policy interchangeably.

2.1 The Case of Perfect Information

When agents have perfect information, their information set includes the history of shocks and regimes, that is, $\mathcal{F}_t = \mathcal{F}^{RE} \equiv \left\{\varepsilon_j^D, \varepsilon_j^S, \varepsilon_j^M, s_j\right\}_{j=1}^t$. Following Davig and Leeper (2007) we write the system (1)-(3) under perfect information as the Markov-Switching Rational-Expectation (MS-RE) system below:

$$y_t(s_t = i) = \sum_{j=1}^{3} \mathbb{E}_t y_{t+1}(s_{t+1} = j) \cdot p_{i,j} - \sigma^{-1}\left[i_t(s_t = i) - \sum_{j=1}^{3} \mathbb{E}_t \pi_{t+1}(s_{t+1} = j) \cdot p_{i,j}\right] + u_t^D \quad (6)$$

$$\pi_t(s_t = i) = \beta \sum_{j=1}^{3} \mathbb{E}_t \pi_{t+1}(s_{t+1} = j) \cdot p_{i,j} + \kappa y_t(s_t = i) + u_t^S \quad (7)$$

$$i_t(s_t = i) = \phi_\pi(s_t = i)\,\pi_t(s_t = i) + \phi_y(s_t = i)\,y_t(s_t = i) \quad (8)$$

where $\mathbb{E}_t(\cdot)$ denotes the perfect-information rational-expectation operator. The terms $y_t(s_t = i)$, $\pi_t(s_t = i)$, and $i_t(s_t = i)$ stand for output gap, inflation, and nominal interest rate conditional on regime $s_t = i$ to occur. As shown by Davig and Leeper (2007), solving the MS-RE model (6)-(8) can be done by applying standard methods (e.g., *Gensys*, Sims (2002)) which are widely used for solving linear rational expectation models with fixed parameters.

2.2 Inflationary Sentiments

Agents conduct Bayesian learning over regimes. Note that since agents know the history of endogenous variables (i.e., y_t, π_t, and i_t), they exactly know when monetary policy is active or passive at any time. Nonetheless, when monetary policy is passive, agents do not know whether the short-lasting regime 2 or the long-lasting passive regime 3 is in place. Agents, thus, have to learn which passive regime is in place in order to form expectations over output gap and inflation.

It is important to emphasize that the degree of agents' pessimism about switching back to the active regime in the future depends on how long monetary policy has been observed to be passive. To see this, note that after having observed that monetary policy has been passive in the last $\tau \geq 1$ consecutive periods, agents believe that monetary policy will be passive in the next period $t+1$ with probability:[5]

$$prob\{s_{t+1} \neq 1 | \mathcal{F}_t\} = \frac{p_{12}\left(\frac{p_{22}}{p_{33}}\right)^\tau + p_{13}}{\frac{p_{12}}{p_{22}}\left(\frac{p_{22}}{p_{33}}\right)^\tau + \frac{p_{13}}{p_{33}}} \quad (9)$$

[5] This result basically comes from applying the Bayes' theorem and then combining the resulting probabilities with the transition matrix P. See Bianchi and Melosi (2011) for a detailed derivation.

This probability measures *inflationary sentiments*, that is, agents' pessimism about how likely the monetary regime will be active in the future.

The probability $prob\{s_{t+1} \neq 1|\mathcal{F}_t\}$ has a number of properties that shed light on how sentiments evolve over time. Since $p_{22} < p_{33}$, this probability can be shown to be monotonically increasing with respect to the number of last consecutive periods τ in which monetary policy has been passive. As the number of periods τ in which monetary policy has been passive increases, agents will become more and more pessimistic about the odds of switching to the active regime in the next period. The reason is that as the central bank deviates from the active regime, agents will get increasingly convinced to be in the long-lasting passive regime 3 from where switching to the active regime is more unlikely because $p_{22} < p_{33}$.

Furthermore, since regime 3 is more persistent than regime 2 (i.e., $p_{22} < p_{33}$), agents' pessimism, $prob\{s_{t+1} \neq 1|\mathcal{F}_t\}$, admits an upper bound and a lower bound. If the central bank has been deviating from the active regime for very long time, the probability of staying in the passive regime in the next period degenerates to the probability of switching to the active regime conditional on being in the long-lasting passive regime 3:

$$\lim_{\tau\to\infty} prob\{s_{t+1} \neq 1|\mathcal{F}_t\} = p_{33} \tag{10}$$

Hence, p_{33} is the upper bound for agents' pessimism. As far as the lower bound is concerned, if the central bank has deviated for only one period (i.e., $\tau = 1$), then equation (9) shows that the probability of staying in the passive regime is an average of the persistence of the two passive regimes p_{22} and p_{33} with weights $p_{12}/(p_{12}+p_{13})$ and $p_{13}/(p_{12}+p_{13})$, respectively. This weighted average is the lower bound for agents' pessimism $prob\{s_{t+1} \neq 1|\mathcal{F}_t\}$. The smaller the conditional probability p_{13}, the smaller the lower bound for the pessimism as the weighted average will be closer to p_{22}. When $p_{13} \simeq 0$ (i.e., central bank has a very strong commitment and always refrains from endorsing long-lasting passive policies), inflationary sentiments are at their *smallest lower bound* p_{22} when the first period of passive policy is observed,

The intuition behind such a lower and upper bound for the waves of agents' pessimism goes as follows. When agents observe the central bank deviating from the active regime for the first period ($\tau = 1$), they mainly expect that the system has switched to the short-lasting passive regime. This happens because a switch to the long-lasting regime 3 is less likely to occur than one to the short-lasting regime 2, as $p_{12} \geq p_{13}$. Since the latter regime is characterized by low persistence (i.e., $p_{22} < p_{33}$), the probability of staying in the passive regime in period $t+1$ will be at its lower bound, which is determined by the strength of the central bank commitment, that is, $p_{12}/(p_{12}+p_{13})$. As monetary policy keeps on deviating from the active regime, agents get increasingly more convinced that monetary policy has entered the long-lasting passive regime and become increasingly more pessimistic about switching to the active regime. When the central bank has deviated from the active regime for a sufficiently large number τ^* of periods, agents are then sure to be in the long-lasting passive monetary regime. Consequently, their pessimism will reach its upper bound, which is the probability that next period's monetary policy will be passive conditional on being in the long-lasting passive regime, p_{33}.

2.3 Solving the Model with Learning

It is very important to emphasize that agents' pessimism about how likely the monetary regime will remain passive in the future (i.e., $prob\{s_{t+1} \neq 1|\mathcal{F}_t\}$) plays a critical role in the Markov-switching model with learning. In fact, unlike the perfect information model, described in Section 2.1, the dynamics of the endogenous variables in the model with learning cannot be fully captured by the three monetary policy regimes (i.e., active, short-lasting passive, and long-lasting passive). The reason is that agents expect different dynamics for next period's output gap and inflation, depending on the degree of their pessimism about a switch to the active regime in the future. Therefore, to solve the Markov-switching model with learning, one has to expand the number of regimes to keep track of both whether the regime is active or passive and the degree of agents' pessimism, i.e., $prob\{s_{t+1} \neq 1|\mathcal{F}_t\}$.

Therefore, learning creates a number of intermediate passive regimes in between the short-lasting passive regime 2 and the long-lasting passive regime 3. Such intermediate regimes reflect different degrees of pessimism while agents are learning about the persistence of realized passive regimes over time. Bianchi and Melosi (2011) show that the Markov-switching model (1)-(3) with three regimes s_t can be recasted in terms of an expanded set of $(\tau^* + 1) > 3$ new regimes τ_t capturing the degree of pessimism associated with the passive regimes at any time:

$$y_t(\tau_t = i) = \sum_{j=1}^{\tau^*+1} \mathbb{E}_t y_{t+1}(\tau_{t+1} = j) \cdot \widetilde{p}_{i,j} - \sigma^{-1}\left[i_t(\tau_t = i) - \sum_{j=1}^{\tau^*+1} \mathbb{E}_t \pi_{t+1}(\tau_{t+1} = j) \cdot \widetilde{p}_{i,j}\right] + u_t^d \tag{11}$$

$$\pi_t(\tau_t = i) = \beta \sum_{j=1}^{\tau^*+1} \mathbb{E}_t \pi_{t+1}(\tau_{t+1} = j) \cdot \widetilde{p}_{i,j} + \kappa y_t(\tau_t = i) + u_t^s \tag{12}$$

$$i_t(\tau_t = i) = \phi_\pi(\tau_t = i)\,\pi_t(\tau_t = i) + \phi_y(\tau_t = i)\,y_t(\tau_t = i) \tag{13}$$

where $i = 1, ..., \tau^* + 1$, $\tau^* > 0$ is an integer such that $prob\{s_{t+1} \neq 1|\tau^*\} \simeq p_{33}$ and

$$\left(\phi_\pi(\tau_t = i), \phi_y(\tau_t = i)\right) = \begin{bmatrix} \left(\phi_\pi^A, \phi_y^A\right), \text{ if } i = 1 \\ \left(\phi_\pi^P, \phi_y^P\right), \text{ if } i > 1 \end{bmatrix}$$

$\mathbb{E}_t(\cdot)$ is the perfect-information rational-expectation operator and $\widetilde{p}_{i,j}$ stands for the *(i,j)* of the transition matrix

$$\widetilde{\mathcal{P}} = \begin{bmatrix} p_{11} & p_{12} + p_{13} & 0 & \ldots & 0 & 0 \\ 1 - \frac{p_{12}p_{22}+p_{13}p_{33}}{p_{12}+p_{13}} & 0 & \frac{p_{12}p_{22}+p_{13}p_{33}}{p_{12}+p_{13}} & \ldots & 0 & 0 \\ 1 - \frac{p_{12}p_{22}^2+p_{13}p_{33}^2}{p_{12}p_{22}+p_{13}p_{33}} & 0 & 0 & \ldots & 0 & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ 1 - \frac{p_{12}p_{22}^{(\tau^*-1)}+p_{13}p_{33}^{(\tau^*-1)}}{p_{12}p_{22}^{(\tau^*-2)}+p_{13}p_{33}^{(\tau^*-2)}} & 0 & 0 & 0 & 0 & \frac{p_{12}p_{22}^{(\tau^*-1)}+p_{13}p_{33}^{(\tau^*-1)}}{p_{12}p_{22}^{(\tau^*-2)}+p_{13}p_{33}^{(\tau^*-2)}} \\ 1 - \frac{p_{12}p_{22}^{\tau^*}+p_{13}p_{33}^{\tau^*}}{p_{12}p_{22}^{(\tau^*-1)}+p_{13}p_{33}^{(\tau^*-1)}} & 0 & 0 & 0 & 0 & \frac{p_{12}p_{22}^{\tau^*}+p_{13}p_{33}^{\tau^*}}{p_{12}p_{22}^{(\tau^*-1)}+p_{13}p_{33}^{(\tau^*-1)}} \end{bmatrix}.$$

where now we have a total of $\tau^* + 1$ regimes:

$$\left[(Active, \tau = 0), (Passive, \tau = 1), (Passive, \tau = 2), ..., (Passive, \tau = \tau^*)\right]$$

Hence, one can recast the Markov-Switching DSGE model with learning in (1)-(3) as a MS-RE system (11)-(13), in which the regimes are re-defined in terms of realized duration of the passive regimes, τ_t. This result allows us to solve the model with regime switches and learning by applying any of the standard methods developed to solve this new class of models. In this paper, we apply the methodology derived by Davig and Leeper (2007) (e.g., *Gensys*).

2.4 Modeling Policy Announcements

Consider the case in which a central bank decides to implement a passive monetary policy for τ_a periods. The bank, however, plans to switch back to active policies in period $\tau_a + 1$. We can study the impact of this policy upon output gap, inflation, agents' expectations and uncertainty in the Markov-switching model with learning by further expanding the set of regimes to $\tau^* + \tau_a + 1$ with the following transition matrix:

$$\widetilde{\mathcal{P}}^A = \begin{bmatrix} \widetilde{\mathcal{P}}_1^A & \widetilde{\mathcal{P}}_2^A \\ \mathbf{0} & \widetilde{\mathcal{P}} \end{bmatrix}$$

where the $\tau_a \times \tau_a$ matrix $\widetilde{\mathcal{P}}_1^A$ and the $\tau_a \times (\tau^* + 1)$ matrix $\widetilde{\mathcal{P}}_2^A$ are defined as

$$\widetilde{\mathcal{P}}_1^A = \begin{bmatrix} 0 & 1 & 0 & \cdots & 0 & 0 \\ 0 & 0 & 1 & \cdots & 0 & 0 \\ 0 & 0 & 0 & \cdots & 0 & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & 0 & \cdots & 0 & 1 \\ 0 & 0 & 0 & \cdots & 0 & 0 \end{bmatrix}, \widetilde{\mathcal{P}}_2^A = \begin{bmatrix} 0 & \cdots & & \cdots & 0 \\ \vdots & \ddots & & \ddots & \vdots \\ 0 & \cdots & & \cdots & 0 \\ \lambda & \cdots & 1-\lambda & \cdots & 0 \end{bmatrix} \tag{14}$$

with $\lambda \in [0, 1]$ and Taylor rule's coefficients:

$$\left(\phi_\pi \left(\tau_t^a = i\right), \phi_y \left(\tau_t^a = i\right)\right) = \begin{bmatrix} \left(\phi_\pi^A, \phi_y^A\right), \text{ if } i = (\tau^a + 1) \\ \left(\phi_\pi^P, \phi_y^P\right), \text{ if } i \neq (\tau^a + 1) \end{bmatrix} \tag{15}$$

Note that the matrix $\widetilde{\mathcal{P}}_1^A$ governs the regime switching during which the accommodative policy is conducted, while the last row of the matrix $\widetilde{\mathcal{P}}_2^A$ are the terminal conditions. The matrix $\widetilde{\mathcal{P}}_2^A$ has all zero elements but two. The first one is the $(\tau_a, 1)$ element, which is equal to λ. The second non-zero element is located at $(\tau_a, \min\{\tau^* + 1, \tau_a + 2\})$. The terminal conditions imply that, after the implementation of the passive policy, a switch to the active policy happens with probability λ. The smaller λ, the less credible the announced switch to the active regime is deemed by the private sector. The degree of credibility of the announcement is clearly related to institutional mechanisms designed to boost central bank's accountability to the announcements she make. The model can be used to measure the degree of central bank's accountability to her announcements in the data.

2.5 Stochastic Volatilities and Welfare

The welfare function is obtained by taking a log-quadratic approximation of the representative household's utility function (see Woodford, 2003 and Gali, 2008). The welfare at time t is given by the following expression

$$\mathbb{W}_t = \sum_{s=0}^{\infty} \beta^s \left[var \left(\pi_{t+s} | \mathcal{F}_t\right) + \frac{\kappa}{\varepsilon} var \left(y_{t+s} | \mathcal{F}_t\right) \right] \tag{16}$$

where κ is the slope of the New Keynesian Phillips curve and ε stands for the elasticity of substitution between goods. The expected welfare gain/loss from transparency (conditional on switching to discretionary monetary policy) is computed as follows:

$$\mathbb{W} = prob\left\{s_t = 2|s_t \neq 1\right\}\left(\mathbb{W}_{SL}^T - \mathbb{W}_{SL}^N\right) + prob\left\{s_t = 3|s_t \neq 1\right\}\left(\mathbb{W}_{LL}^T - \mathbb{W}_{LL}^N\right) \tag{17}$$

where $\left(\mathbb{W}_{SL}^T - \mathbb{W}_{SL}^N\right)$ and $\left(\mathbb{W}_{LL}^T - \mathbb{W}_{LL}^N\right)$ denote the cumulative change in welfare when the central bank announces a policy of short-lasting and long-lasting discretion, respectively. In symbols, $\left(\mathbb{W}_{SL}^T - \mathbb{W}_{SL}^N\right) = \sum_{t=1}^{4}\left(\mathbb{W}_{SL,t}^T - \mathbb{W}_{SL,t}^N\right)$, where $\mathbb{W}_{SL,t}^T$ and $\mathbb{W}_{SL,t}^N$ stand for the welfare at time t associated with short-lasting discretion, computed as in equation (16), under transparency and no transparency, respectively. Analogously, the gain from transparency associated with long-lasting discretion is given by $\left(\mathbb{W}_{LL}^T - \mathbb{W}_{LL}^N\right) = \sum_{t=1}^{20}\left(\mathbb{W}_{LL,t}^T - \mathbb{W}_{LL,t}^N\right)$, where $\mathbb{W}_{LL,t}^T$ and$\mathbb{W}_{LL,t}^N$ stand for the evolution of welfare associated with long-lasting discretion, computed as in equation (16), under transparency and no transparency, respectively. The terms $prob\left\{s_t = 2|s_t \neq 1\right\}$ and $prob\left\{s_t = 3|s_t \neq 1\right\}$ denote the ergodic probability of monetary policy of being short-lasting and long-lasting passive (conditional on being passive). Thus, when we measure the welfare gain/loss from introducing transparency, we take into consideration the long-run relative frequency of being in each of the two discretionary regime.

Equation (16) makes it explicit the link between households' welfare and the degree of uncertainty about future macroeconomic developments (i.e., inflation and output gap). Note that, unlike in DSGE models with fixed coefficients, here welfare is not only a function of the ergodic variability of inflation and output gap. The short-term evolution of uncertainty about inflation and the output gap also matters for quantifying the welfare associated with policy actions. We follow the approach developed by Bianchi (2011) to compute the pattern followed by stochastic volatilities as the policy is conducted.

3 Using the Model for Monetary Policy Evaluation

In this section, the paper calibrates the model to the U.S. economy. We show that constrained discretion is an approach to monetary policy that can be rationalized in the modeling framework proposed in the paper. Furthermore, we show how the model can be used to evaluate welfare implications associated with the introduction of transparency for a given monetary policy strategies (i.e., $\phi_\pi(s_t)$, $\phi_y(s_t)$, and $\mathcal{P}$).

Section 3.1 deals with the calibration of the model parameters. Section 3.2 shows the dynamics of inflationary sentiments as the central bank deviates from active policy of inflation stabilization. In Section 3.3, the paper uses the model to evaluate the welfare implications of increasing the transparency.

Parameter	Value	Parameter	Value	Parameter	Value	Parameter	Value
$\phi_\pi (s_t = 1)$	2.19	σ^{-1}	1.00	ρ_d	0.75	p_{11}	0.750
$\phi_\pi (s_t \neq 1)$	0.85	β	0.99	σ_d	0.23	p_{22}	0.750
$\phi_y (s_t = 1)$	0.25	κ	0.17	ρ_s	0.95	p_{33}	0.950
$\phi_y (s_t \neq 1)$	0.50	ε	6.00	σ_s	0.80	p_{12}	0.245

Table 1: Baseline Calibration

3.1 Calibration

We calibrate the model to the U.S. economy. The parameter values are chosen to be in line with the values estimated by Lubik and Schorfheide (2004). Table 1 reports the parameter values. The transition probability matrix $\mathcal{P}$ is calibrated using the estimates in Bianchi (2010b) who finds that the long-lasting passive regime mostly characterizes the monetary policy in the 1960s and 1970s whereas the active and the short-lasting regime describes the Federal Reserve's behaviors after the 1980s. While no clear consensus has emerged either on the frequency or on the average duration of short-lasting deviations after the 1980s, anecdotal evidence suggests that these deviations have been quite frequent. During Greenspan's tenure, starting in the Summer of 1987, inflation has been de-emphasized in favor of alternative targets during two stock market crashes, two foreign financial crises, and two jobless recoveries. These episodes have happened one every three years on average and usually have lasted a few months or more than a year. Bianchi (2010b) documents that from 1981 to 2007, monetary policy has been passive only during the short recession of 1991. These findings are in line with our calibration of p_{22}, implying an average duration of four quarters for the short-lasting passive regime. Based on Bianchi (2010b), we calibrate the average duration of the passive policies during the 1960s and the 1970s (i.e., the long-lasting passive regime) to be equal to twenty quarters. The implied ergodic distribution for the three regimes is $[0.48, 0.47, 0.05]$, showing that the long-lasting passive regime is quite rare to occur while deviations to the short-lasting passive regime are quite common. This ergodic distribution seems to square well with the idea that the Federal Reserve has mainly followed a policy strategy that closely resembles *constrained discretion*, implying that monetary policy frequently switches from active to short-lasting passive.

Note that since agents are rational Bayesian learner, their beliefs are consistent in equilibrium. Thus the matrix $\mathcal{P}$ plays a dual role in the model: the transition matrix for monetary policy regimes and agents' *a-priori* beliefs about the evolution of these regimes. Under the latter interpretation of the matrix $\mathcal{P}$, long-lasting switch to discretionary policy are considered by agents as very infrequent, reflecting the Federal Reserve's strong commitment to refraining from 1970s-type (long-lasting) passive policies that would jeopardize inflation stability. Thus, the coefficient controlling the perceived strength of commitment to inflation stabilization is given by $p_{12}/\left(p_{12}+p_{13}\right)$ and is equal to 0.98,[6] which suggests a fairly strong commitment.

3.2 Evolution of Beliefs

Suppose that the central bank follows the active regime at time 0 and enters one of the two passive regimes for τ periods. Figure 1 shows the evolution of agents' beliefs about the current monetary regime (i.e., the top chart) and about next quarter's monetary regime (i.e., the bottom chart) as the duration of passive regime, τ, grows large. The top chart shows that as the central bank switches to the passive regime (i.e., $\tau = 1$), agents mainly expect to be in the short-lived passive regime as the probability of switching to regime 2 conditional on being in the active regime is bigger than the conditional probability of switching to regime 3 (i.e., $p_{12} = 0.245 > p_{13} = 0.005$). As the central bank keeps on staying in the passive regime, agents get more and more convinced that the system has entered to the long-lasting regime. This result stems from having assumed that regime 2 is less persistent than regime 3 (i.e., $p_{33} = 0.95 > p_{22} = 0.75$).

The bottom chart illustrates that, as the first deviation to passive policy is observed (i.e., $\tau = 1$), agents' belief about observing a passive policy in the next period (i.e., what we called inflationary sentiments in Section 2.2) deteriorates compared to their belief in the previous period when monetary policy was active (i.e., $\tau = 0$). At the very first deviation, the probability that next period's monetary will be passive is slightly above $p_{22} = 0.75$. As the central bank keeps on deviating, inflationary sentiments barely move. Only after eight quarters of consecutive deviations, sentiments take off and agents' belief about observing a passive policy next quarter rapidly converges to the red dashed line (i.e., the upper bound $p_{33} = 0.95$). Note that as $\tau \geq 24$, agents are sure to be in the long-lasting passive regime and the probability of switching to the active regime become virtually identical to the conditional probability p_{31}.

Consider what happens if the central bank has a weaker commitment to inflation stabilization than the Federal Reserve. This can be captured by setting $p_{12} = p_{13} = 0.125$, implying a weaker commitment to active policy, $p_{12}/\left(p_{12}+p_{13}\right) = 0.50 < 0.98$. The evolution of beliefs is reported in Figure 2. The top chart illustrates that as the very first passive policy is observed (i.e., $\tau = 1$), agents believe that the observed deviation can be short-lasting or long-lasting with equal probability. Comparing Figures 1 and 2 reveals that, at the first deviation, agents expect that a prompt switch to active policy in the future is more

[6] This coefficient is the probability of switching to the short-lasting passive regime conditional on observing the first deviation from active policy (i.e., $\tau = 1$).

unlikely under weaker commitment. Inflationary sentiments suddenly take off after the very first period of passive policy. This is documented in the bottom chart of Figure 2, which shows that the first deviation (i.e., $\tau = 1$) suddenly pushes up inflationary sentiments (i.e., blue line with circles) far away from $p_{22} = 0.75$ and fairly close to the upper bound p_{33}.

3.3 Welfare-Based Evaluation of Monetary Policy Communication

We use the model to study the welfare implications of introducing transparency. Given the calibration discussed in Section 3.1, the U.S. monetary policy has been characterized by two types of discretionary policy: (i) *short-lasting discretion*, that is four quarters of passive monetary policy, which is the typical (i.e., expected) duration of the short-lasting passive regime and (ii) *long-lasting discretion*, that is, twenty quarters of passive policy, which is the typical (i.e., expected) duration of the long-lasting passive regime. We consider the case when these typical policies are announced beforehand (i.e., transparency) and that when no announcement is made (i.e., no transparency). For the former case, we need to set the value for the parameter λ, which controls the credibility of policy announcements. For the time being, we consider the case of policy announcements that are deemed as fully credible by agents, that is, $\lambda = 1$. We will relax this assumption shortly.

For the sake of brevity, we do not show the evolution of uncertainty about output gap. We focus on uncertainty about inflation, since it is the one that matters the most for welfare $\mathbb{W}_t$. Figure 3 shows how uncertainty about inflation at different horizons evolves as the Federal Reserve implements a long-lasting discretionary policy (i.e., twenty periods of consecutive deviations from active policy) followed by a switch to the active regime. The two graphs on the right report the evolution of uncertainty $var\left(\pi_{t+s}|\mathcal{F}_t\right)$ across horizons s[7] and time t in the case of transparency and no transparency. Note that under transparency the surface is characterized by a *valley* because uncertainty is pegged down at the time when monetary policy has been (credibly) announced to become active. Nonetheless, note that uncertainty increases at short horizons when an announcement is made. This happens because agents know that policy will be passive for twenty consecutive periods.

When no announcement is made, the bottom right plot features a hump as the discretionary policy is implemented (i.e., as t grows large). This hump is due to the fact that -as illustrated in Figure 1 - agents become increasingly more pessimistic about a prompt return to active monetary policy as the discretionary policy is implemented. These sentiments foster agents' concern about the central bank's ability of limiting the inflationary consequences of future demand and supply shocks. As a result, the bottom rightward plot of Figure 3

[7] Note at the horizon $s = 0$, the uncertainty is zero as agents observe current inflation. The graphs do not report the zero horizon uncertainty.

reports that agents become more uncertainty about future inflation developments at every horizon as the passive policy is implemented. Rising uncertainty has a negative impact on welfare $\mathbb{W}_t$. See equation (16).

The leftward graphs are the snapshots of the evolution of uncertainty about inflation across horizon taken at the beginning (the top chart) and at the end of the discretionary policy (the bottom chart). Short-horizon uncertainty promptly goes up after the announcement is made. If no announcement is made, short-horizon uncertainty is very similar to the uncertainty that would arise if agents were fully convinced to be in the short-lasting passive regime (the red solid line). This happens because central bank's commitment is quite high (i.e., $p_{13} = 0.005$). When the central bank announces her policy course (the dashed red line with squares) twenty-quarter-ahead uncertainty is pegged down as agents are fully ($\lambda = 1$) convinced that the central bank will become active after twenty quarters. This effect produces a hump-shaped dynamic of uncertainty about inflation across horizon in the case of transparency.

The bottom leftward plot reports the evolution of uncertainty at the end of the policy. Here, uncertainty associated with transparency is quite lower than that associated with no transparency at all horizons. The reason is that under transparency agents know that the central bank will switch to active policy with probability one in the next period. In contrast, under no transparency, uncertainty at every horizon will be at its highest because inflationary sentiments are high at the end of the discretionary policy. Under no transparency, the evolution of uncertainty is fairly close to what we observe when agents are at most pessimistic about observing a prompt switch to active policy, that is, when they know with certainty that monetary policy is in the long-lasting passive regime (the red solid line). Quite interestingly, when the central bank does not announce her policy, long-lasting discretionary policy gives rise to excess uncertainty as the planned deviations approaches the end. This effect is illustrated in the bottom leftward plot of Figure 3, in which uncertainty follows a hump-shaped pattern and overshoots the long-run ergodic level of uncertainty.

Figure 4 reports the dynamic of welfare $\mathbb{W}_t$ as a long-lasting discretionary policy is implemented. Announcing long-lasting discretionary policies is found to improve welfare in the medium-long run as the announcement pegs down inflationary sentiments. The bottom leftward chart of Figure 3 reports the evolution of uncertainty about future inflation, which is the component that mainly drives welfare $\mathbb{W}_t$, across horizons at the end of the policy. At this stage, uncertainty at every horizon is smaller under transparency because agents know that the observed discretionary policy is soon coming to an end. This keeps inflationary sentiments low at the end of the announced discretionary policy. Note that, at the beginning of a long-lasting discretionary policy, transparency causes short-horizon uncertainty about future inflation to jump. This feature is illustrated by the hump-shaped dynamic of uncertainty in the top leftward chart of Figure 3. This feature explains why Figure 4 reports that, at the beginning of the policy, welfare is lower under transparency.

Figure 5 reports the evolution of uncertainty about future inflation associated with the typical short-lasting discretionary policy , which consists of four consecutive quarters of deviations from active policy. Two features are worthwhile emphasizing in Figure 5. First, unlike the case of long-lasting discretion in Figure 3, at the beginning of the policy (top leftward chart), announcement does not cause short-horizon uncertainty to overshoot its ergodic level. The reason is that the duration of the announced discretionary policy is much smaller, implying that the anchoring-the-sentiments effect dominates the short-horizon uncertainty due to announcing discretionary policy. In fact, uncertainty is always smaller (but the one at one-quarter horizon) under transparency. Second, at the end of the policy (bottom leftward chart), the dynamics of uncertainty appear to be virtually the same regardless of whether the policy was announced or not. The reason for this behavior is that discretionary policy is too short to ignite inflationary sentiments under no transparency. Note that uncertainty at the end of the policy is much smaller than its upper-bound (i.e., the solid red line), which is attained when agents are certain to be in the long-lasting passive regime, at every horizon.

Figure 6 reports the evolution of welfare (top chart) and its components (middle and bottom diagrams) as a short-lasting discretionary policy is conducted by the Federal Reserve. Transparency improves welfare of the policy of interest in every period. Now we can use the model to evaluate whether the Federal Reserve would gain or lose from being transparent, given the calibrated policy structure ($\phi_\pi(s_t)$, $\phi_y(s_t)$, and the matrix $\mathcal{P}$). Using Equation (17) to quantify the welfare gain/loss from welfare reveals that that transparency improves welfare.

In the next sections we will focus on three important cases. First, we consider the welfare implications of transparency for a central bank with a weaker commitment. Second, we study to what extent the lack of credibility of policy announcements affects the desirability of transparency. Third, we address the issue of how the persistence of cost-push shocks changes the welfare gain/loss from transparency.

3.3.1 Weaker Commitment

In this section, we study the case in which the central bank has a weaker commitment against inflation (say, $p_{12} = p_{13} = 0.125$). The associated ergodic distribution of monetary regimes is now $(0.25, 0.125, 0.625)$: Monetary policy is almost always passive and mainly characterized by long-lasting periods of discretionary policy. The remaining parameters are set to be the same as those of the previous section.

Figure 7 reports the evolution of uncertainty about future inflation when the long-lasting discretionary policy is conducted by a central bank that has a weaker commitment against inflation. In the top leftward chart, the short-horizon uncertainty suddenly goes up after the announcement is made, similarly to the case of strong commitment. However, unlike the case with strong commitment, when no announcement is made, the response of short-term uncertainty is much higher than that under transparency, at the beginning of the policy (compare with the top leftward chart of Figure 3). The reason is that, at the very first period of discretionary policy, a weaker commitment causes agents to become suddenly more pessimistic about observing a switch to the active monetary policy in the future. Therefore, the excess uncertainty generated upon the announcement is smaller than that under strong commitment. Since the announcement is deemed as fully credible (i.e., $\lambda = 1$), announcing the policy beforehand has the effects of pegging down medium-horizon uncertainty at the beginning of the policy. In contrast, comparing the top leftward charts of Figure 7 and 3 reveals that, when no announcement is made, a weak commitment implies a fairly high medium-horizon uncertainty at the beginning of the policy. The reason is that a weak commitment implies that agents expect that long-lasting discretion is more likely to occur in the future. As a result, medium-term uncertainty turns out to be much smaller under transparency. At the end of the policy, the bottom leftward charts of Figure 7 and 3 show that the lack of transparency causes uncertainty (at every horizon) to attain its upper bound (i.e., the red solid line), which arises when agents know with certainty that the regime is in the long-lasting passive regime. In contrast, transparency causes uncertainty at every horizon to stay below this upper-bound by anchoring inflationary sentiments.

Figure 8 shows that transparency improves the welfare associated with long-lasting discretion performed by a central bank with a weak commitment. Unlike the case of strong commitment, welfare gains from transparency are always positive during the implementation of the policy. The reason is twofold and has been discussed when we compared the top leftward charts of Figure 3 and 7. First, the excess uncertainty generated upon the announcement is smaller than that under strong commitment. Second, a weak commitment implies higher medium-horizon uncertainty under no transparency.

Transparency improves the welfare associated with short-lasting discretion under a weak commitment too. These gains are bigger than those obtained by a central bank with strong commitment. The reason is that under weak commitment inflationary sentiments and hence uncertainty take off at the very first period of an unannounced discretionary policy.

Equation (17) reveals that welfare gains from transparency $\mathbb{W}$ are positive, suggesting that central banks with a weak commitment gain from transparency. Furthermore, we find that a central bank with a weak commitment benefits relatively more from transparency than a central bank with strong commitment. In the particular numerical case considered in this section (i.e., $p_{12} = p_{13}$), gains from transparency are bigger than that under strong commitment by a factor of sixteen. As discussed above, this result is driven by the high uncertainty at all times and horizons generated by discretionary policies conducted by central banks with a weak commitment.

Importantly, the model predicts that the gains from transparency are smaller for those central banks that have built up a strong commitment against inflation. This prediction squares well with the observation that the Federal Reserve Bank and the European Central Bank are arguably less transparent than other banks that have been arguably less successful at building up a strong commitment (e.g., the central banks of Brazil, Mexico, and Chile). Recall that so far we have compared welfare gains from transparency for central bank with different degree of commitment assuming that policy announcements are deemed to be fully credible. This is a fairly strong assumption as one may argue that in practice the credibility of a policy announcement is somehow related to the central bank's commitment. We relax this assumption in the next section.

3.3.2 Imperfect Credibility of Announcements

In this section, we consider the case in which announcements made by the central bank are not deemed as fully credible by agents. More specifically, we consider the case in which the announcement is deemed as non credible, that is, $\lambda = prob\{s_{\tau_a+1} = 1|\tau_a\}$. Note that the value for λ implies that the probability of switching to the active regime after the announced period of discretionary policy depends on the level of agents' pessimism after having observed τ_a consecutive periods of discretionary policy. Note that $prob\{s_{\tau_a+1} = 1|\tau_a\} = 1 - prob\{s_{\tau_a+1} \neq 1|\tau_a\}$, where $prob\{s_{\tau_a+1} \neq 1|\tau_a\}$ is the measure for the pessimism at the end of the discretionary policy in Equation (9).

How does the lack of credibility of announcements affect the welfare implications of transparency? Figure 9 answers this question for the case of long-lasting discretion. If one compares the top leftward chart with that in Figure 3, one can clearly see that non-credible announcements fail to peg down uncertainty at medium horizons. Yet, recall that pegging down medium-horizon uncertainty is the main source of gains from transparency. Thus, the model predicts that transparency under no credibility of policy announcements always decreases welfare.

The model predicts that central bank's ability of making credible announcement is absolutely essential to improve welfare. Therefore, enhanced transparency has to be accompanied with reforms aimed at raising the credibility of announcements. For instance, it is desirable to back up transparency with mechanisms that raise the accountability of the central bank for her announcements so as to convince the private sector to take central bank's communication seriously. These predictions square well with the reality. Since 1990s, several countries[8], which have been quite unsuccessful in keeping inflation low and stable, have adopted the *inflation targeting*. The *inflation targeting* is considered as a form of *constrained discretion* in which transparency and accountability for central bank's policy objectives are greatly emphasized (Bernanke and Mishkin, 1997). With no exceptions, all the countries that have adopted the *inflation targeting* have reformed their central bank with the aim to make them more transparent and accountable for their announced policy objectives. From the perspective of our model, these reforms are essential to justify the undeniable success[9] of these countries in controlling inflation after the introduction of the *inflation targeting*.

3.3.3 Transparency and Persistence of Cost-Push Shocks

In this section, we study the case in which the cost-push shock is less persistent, say $\rho_s = 0.5$. The goal is to shed light on how the gains from transparency are related to the persistence of shocks. The central bank is assumed to have developed a strong commitment to inflation stabilization (i.e., the U.S. case in Table 1) and can credibly make announcements (i.e., $\lambda = 1$).

The model predicts that persistence matters a lot for the welfare gains associated with persistence: the more persistent the cost-push shocks, the larger the gains from transparency. In the numerical low-persistence example studied in this section, gains from transparency are negligible, albeit still positive. The reason is that low persistence implies that uncertainty about macroeconomic developments (e.g., inflation) converges more quickly to its ergodic level. This implies that, *ceteris paribus*, upon the announcement, uncertainty about future inflation rapidly reaches its higher long-run level. The top-leftward chart of Figure 10 illustrates the quick dynamic of uncertainty about future inflation for the case of low-persistence cost-push shock and long-lasting discretion. It follows that the gains from transparency associated with long-lasting discretionary policy are negative. Comparing the top charts of Figure 11 and 4 reveals that the welfare lines associated with transparency and no transparency cross each other much later when shocks are less persistent. Thus, transparency

[8] The list of industrialized countries that have adopted the *inflation targeting* since 1990s is long and includes the United Kingdom, New Zealand, Australia, Finland, Spain and Israel. Several emerging countries have adopted the *inflation targeting* as well. A detailed survey is conducted in Bernanke, Laubach, Mishkin, and Posen (1999).

[9] Mishkin and Schmidt-Hebbel (2007) find empirical evidence that inflation targeting helps countries have smaller inflation response to oil-price and exchange-rate shocks. Other studies (e.g., Gürkaynak, Levin, and Swanson, 2007, Levin, Natalucci, and Piger, 2004, and Castelnuovo, Nicoletti-Altimari, and Palenzuela, 2003) find that inflation expectations appear to be more anchored for inflation targeters than nontargeters: that is, inflation and inflation expectations react less to shocks to actual inflation for targeters than nontargeters, particularly at longer horizons.

depresses welfare in case of long-lasting discretionary policy in face of low-persistence shock. Furthermore, it is possible to show that introducing transparency may even lead to welfare loss if cost-push shocks have sufficiently low persistence.

4 The Macroeconomic Effects of Transparency

Central banks are usually very concerned about how private sector's inflation expectations react to short-run accommodative monetary policy. The issue of for how long the central bank can de-emphasize inflation stabilization and, at the same time, keep inflation expectations low and stable is absolutely essential for *constrained discretion* to work successful. Too long deviations from inflation stabilization are likely to rise concerns about how seriously committed the central bank is in fighting inflation in the medium and long-run. When the private sector starts questioning the solidity of central bank's commitment inflation expectations and inflation rise. To shed light on this important issue, we use the model to simulate the effects of accommodative policies on inflation expectations and inflation in the aftermath of a cost-push shock. We consider two cases: (i) the case of transparency, in which the central bank communicates the planned policy course beforehand; (ii) the case of no transparency, in which the central bank does not communicate her actions beforehand.

Figure 12 shows the impulse response functions of one-quarter-ahead inflation expectation, inflation, and the output gap to a one-standard-deviation persistent ($\rho_s = 0.99$) cost-push shock when the central bank performs a long-lasting passive monetary policy (i.e., twenty quarters of consecutive deviations followed by active monetary policy forever thereafter). If the central bank does not make any announcement, inflation expectations and inflation sluggishly grow over a long time span of five years in the aftermath of the shock. It is very important to emphasize that inflation is gradually rising while the size of the shock is (slowly) decreasing over time. Such a divergent pattern of inflation and the size of the shock cannot be obtained in standard (fixed or time-varying parameter) DSGE models with perfect information as it is induced by the gradual rise of inflationary sentiments (i.e., agents' pessimism about observing a switch to the active regime in the near future). The passive response of the central bank is interpreted by agents, at first, as a short-lasting deviation. As the central bank keeps on conducting the accommodative policy, inflationary sentiments take off and inflation steadily rises. Eventually when agents get fully convinced to be in the long-lasting passive regime, inflation expectations and, hence, inflation are very high. This happens because inflationary sentiments have attained their upper-bound (see Figure 1) and, at the same time, the size of the shock is still quite large, albeit smaller than that at the beginning.

Quite interestingly, we observe that inflation expectations and inflation grow at a faster rate as the central bank keeps on deviating from the active regime. During the first eight quarters of accommodative policy, inflation and expectations move very slowly. Only after two years of accommodative policy, inflation and expectations rapidly take off and double in value within the next three years. This change in the growth rate is linked to the varying speed of adjustment of sentiments, which has been illustrated in Figure 1. Figure 13 reports the impulse response functions of inflation expectations, inflation, and the output gap as the central bank responds to a persistent cost-push shocks with a short-lasting passive policy (i.e., four quarters of consecutive deviations from active policy).

Figures 13 and 12 show that when the central bank credibly (i.e., $\lambda = 1$) announces her policy course beforehand, inflation expectations and inflation steadily decreases during the implementation of the passive policy. When a credible announcement is made, inflationary sentiments fall down as the policy is implemented. Since agents know that policy will be passive for the first quarters, sentiments and hence inflation suddenly increase upon the announcement. Yet as the policy is implemented, inflationary sentiments decreases because agents know that the time at which the monetary policy will switch to active is approaching. This pattern for sentiments induces inflation to gradually decrease during the implementation of an accommodative policy that has been announced beforehand.

Figure 14 reports the response of inflation expectations, inflation, and the output gap to a persistent cost-push shock under weak commitment (i.e., $p_{13} = p_{12} = 0.125$) when the central bank performs a long-lasting passive policy. If the central bank does not communicate her policy beforehand, the inflation-output gap trade-off suddenly deteriorates. The reason for this result goes as follows. Under weak commitment, sentiments suddenly jump up upon the first central bank's accommodation of the shock, quickly deteriorating the inflation-output gap trade-off. Paraphrasing Bernanke (2003), if a central bank has failed to establish a strong commitment, *discretion* gets *constrained* too quickly, suppressing the central bank's leeway in accommodating cost-push shocks. In the case of a weak commitment, transparency has the effect of improving the medium-term inflation-output gap trade-off by anchoring inflationary sentiments.

Figure 15 reports the response of inflation expectations, inflation, and the output gap to a persistent cost-push shock when the central bank cannot make credible announcements, that is $\lambda = prob\{s_{\tau_a+1} = 1|\tau_a\}$. When central bank's announcements are not deemed as credible by agents, transparency fails anchoring inflationary sentiments in the medium run. Furthermore, at the beginning of the policy, the announcement will persuade agents that monetary policy is likely to deviate for much longer than the announced twenty quarters. As a result, the inflation-output gap trade-off dramatically worsens.

5 Concluding Remarks

We develop a DSGE model in which the central bank adheres to a monetary policy scheme that goes under the name of *constrained discretion*. *Constrained discretion* is an approach to monetary policy that represents a middle ground between two polar principles in the classical debate about optimal monetary policy: rules vs. discretion. Unlike ironclad rules, constrained discretion allows the central bank some leeway in adjusting the adverse consequences of shocks on output and employment. Unlike unfettered discretion, the central bank understands that prolonged period of discretionary policy will unavoidably lead to instability of inflation expectations and inflation with associated uprise of broader economic and financial uncertainty, which will be ultimately harmful for welfare.

In the model, the central bank alternates active policies aimed to stabilize inflation and passive policies with the goal to stabilize the output gap. Agents observe when monetary policy becomes passive but they face uncertainty regarding its nature. Importantly, when passive policies are observed, they cannot rule out the possibility that a persistent sequence of deviations is in fact a return to the kind of monetary policy that characterized the 1970s. Instead, they have to keep track of the number of deviations to learn if monetary policy entered a short lasting or a long lasting period of passive monetary policy. The longer the central bank's deviation from the active policy is, the more pessimistic about the evolution of future monetary policy agents become. This implies that as the central bank keeps deviating, both the inflation-output gap trade-off and the welfare deteriorate.

When the model is calibrated to the U.S. data, we find that inflationary sentiments sluggishly rise as the Federal Reserve deviates from active monetary policy. Such a dynamic for sentiments implies that (i) inflation drifts up for several years in response to a cost-push shock and (ii) the Federal Reserve has a large leeway in accommodating this type of shocks. Increasing the transparency of the Federal Reserve is found to improve welfare by anchoring inflationary sentiments. Gains from transparency are even more sizeable in periods when the persistence of shocks is high and for countries whose central bank has failed establishing a strong commitment to keeping inflation under control.

A nice feature of the paper is to introduce a convenient way to model waves of pessimism about the future monetary policy course. In the simple setting studied in this paper, we have shown that waves of agents' pessimism or optimism about future policy actions play a central role in shaping the response of macroeconomic variables and households' welfare to macroeconomic shocks in forward-looking rational expectations models. Expanding the analysis to state-of-the-art monetary DSGE models (e.g., Christiano, Eichenbaum, and Evans, 2005 and Smets and Wouters, 2007) would be of great interest. Characterizing the optimal monetary policy in a model in which monetary policy influences the dynamic of inflationary sentiments is also an important venue for future research.

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Figures

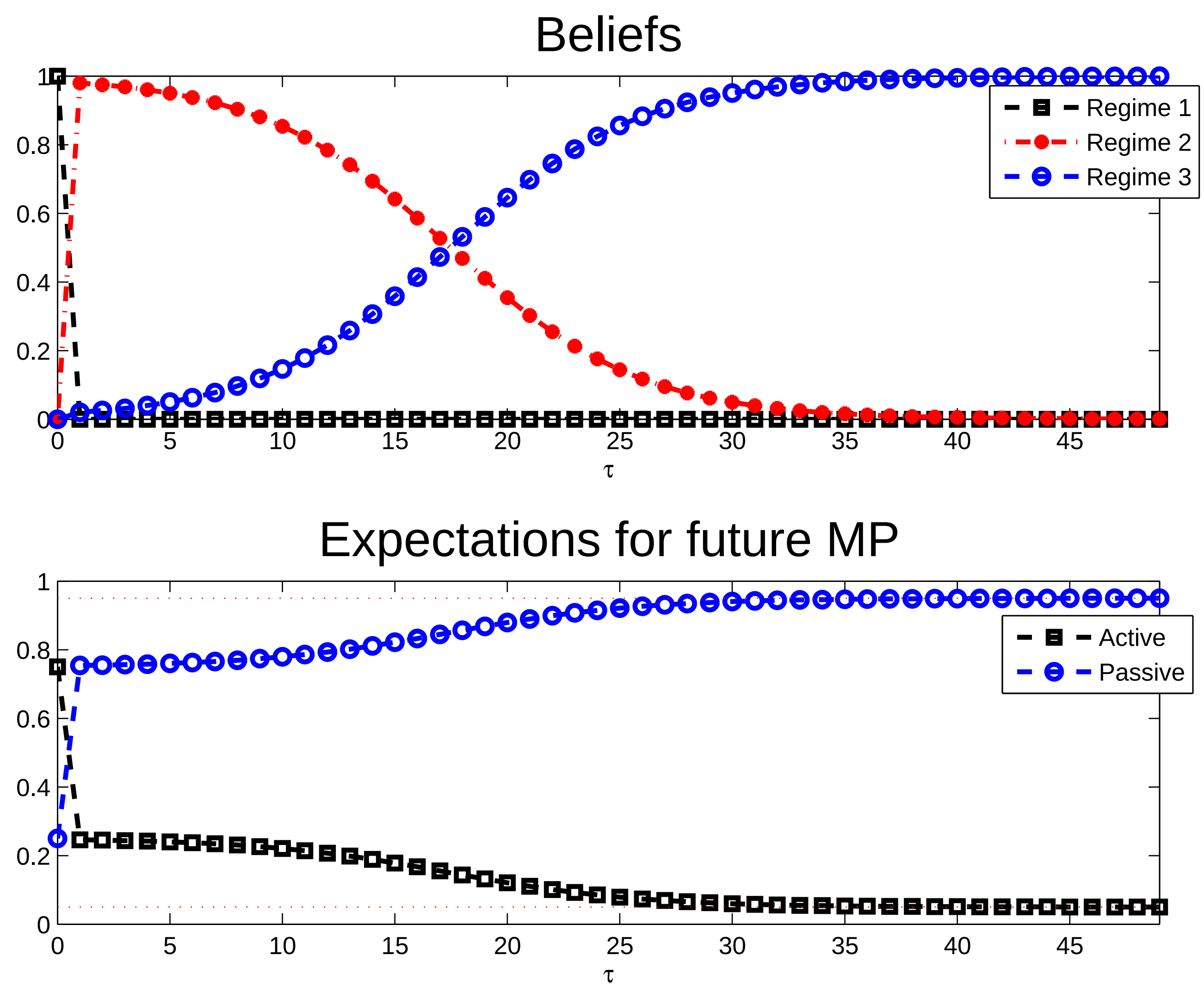

Figure 1: Evolution of Beliefs about Current and Future Monetary Policy Regime as Monetary Policy Stays in the Passive Regime: Baseline Calibration

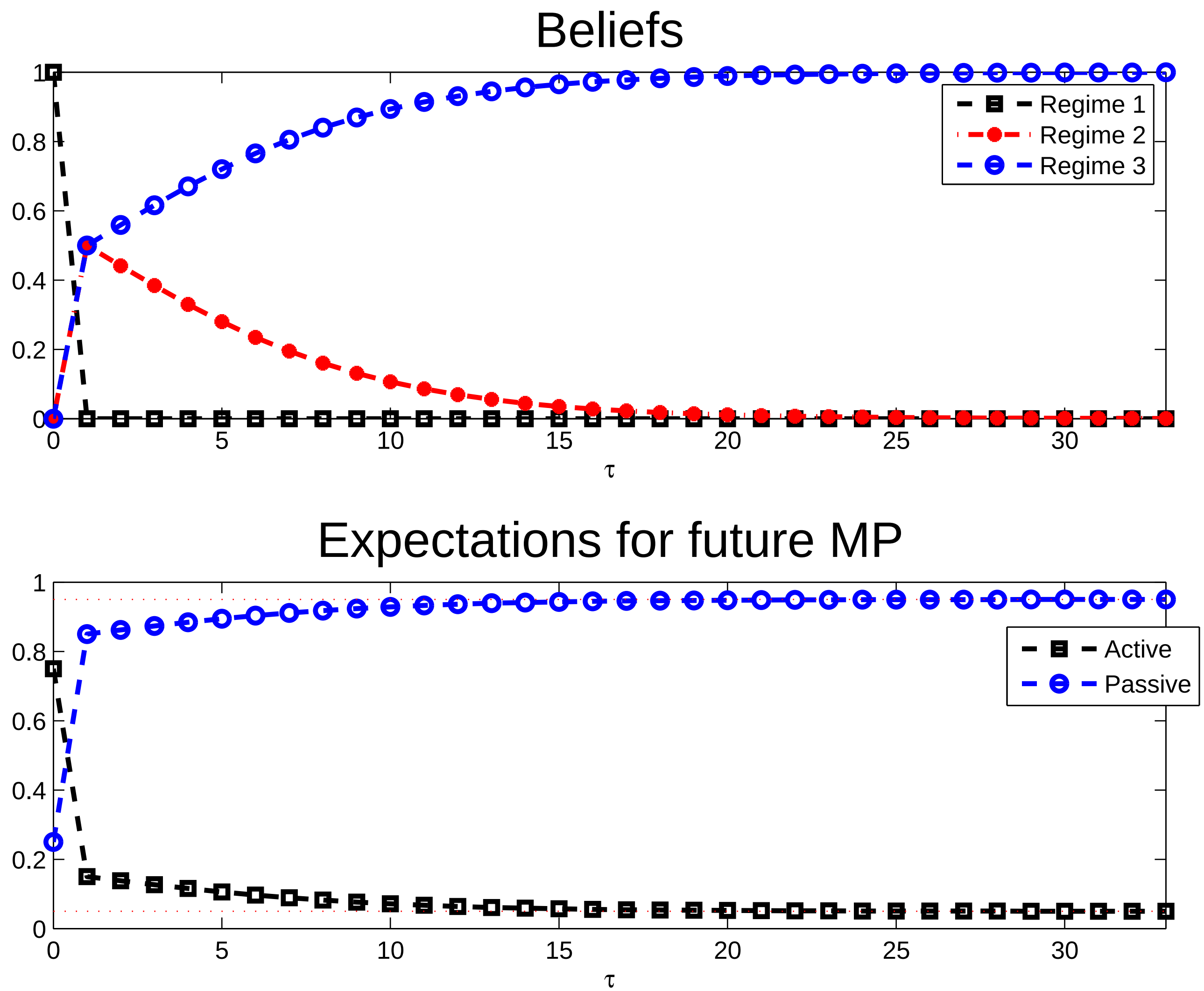

Figure 2: Evolution of Beliefs about Current and Future Monetary Policy Regime as Monetary Policy Stays in the Passive Regime: Weaker Commitment

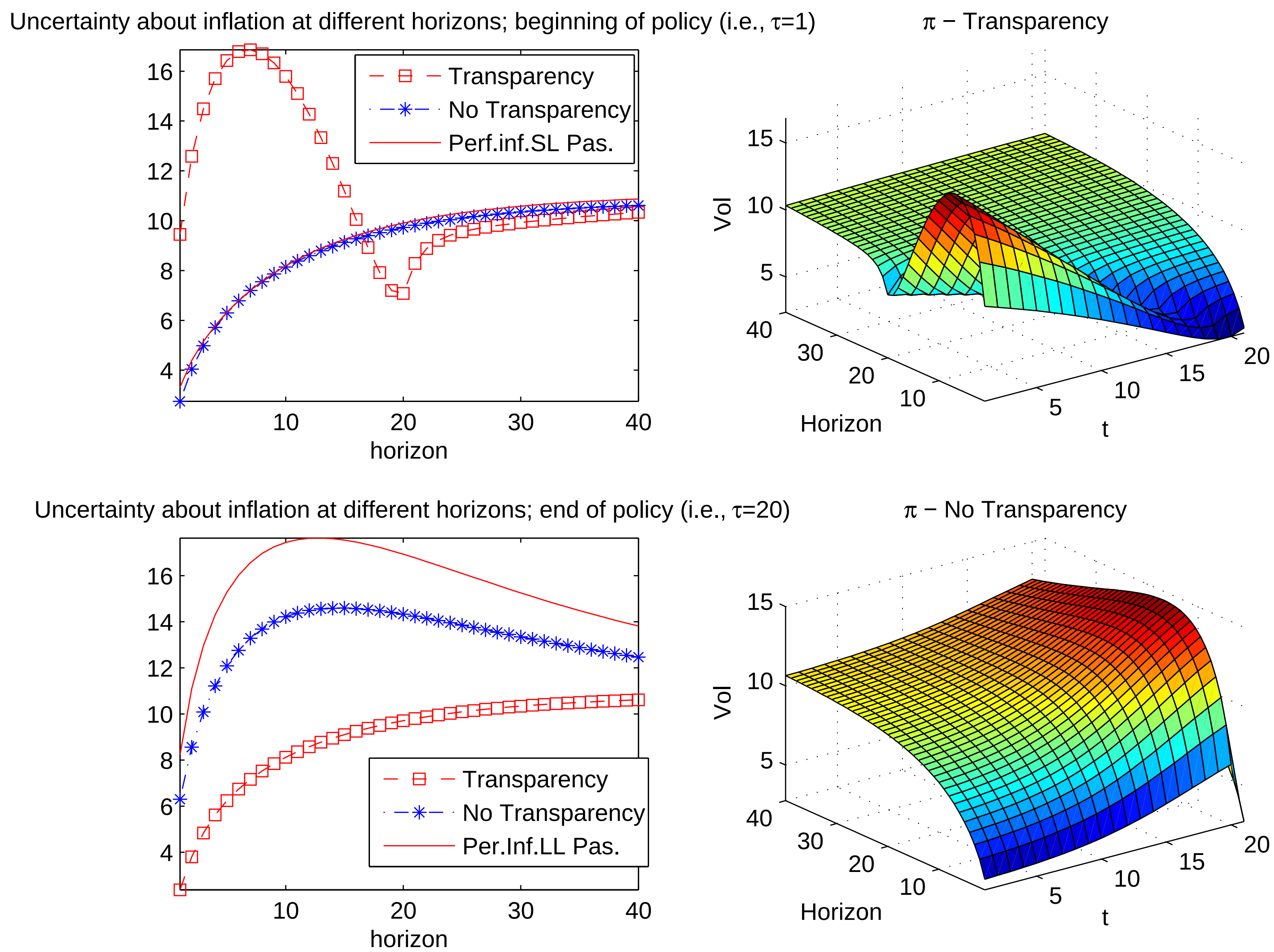

Figure 3: Evolution of Uncertainty: The Case of Long-Lasting Discretion and Strong Commitment

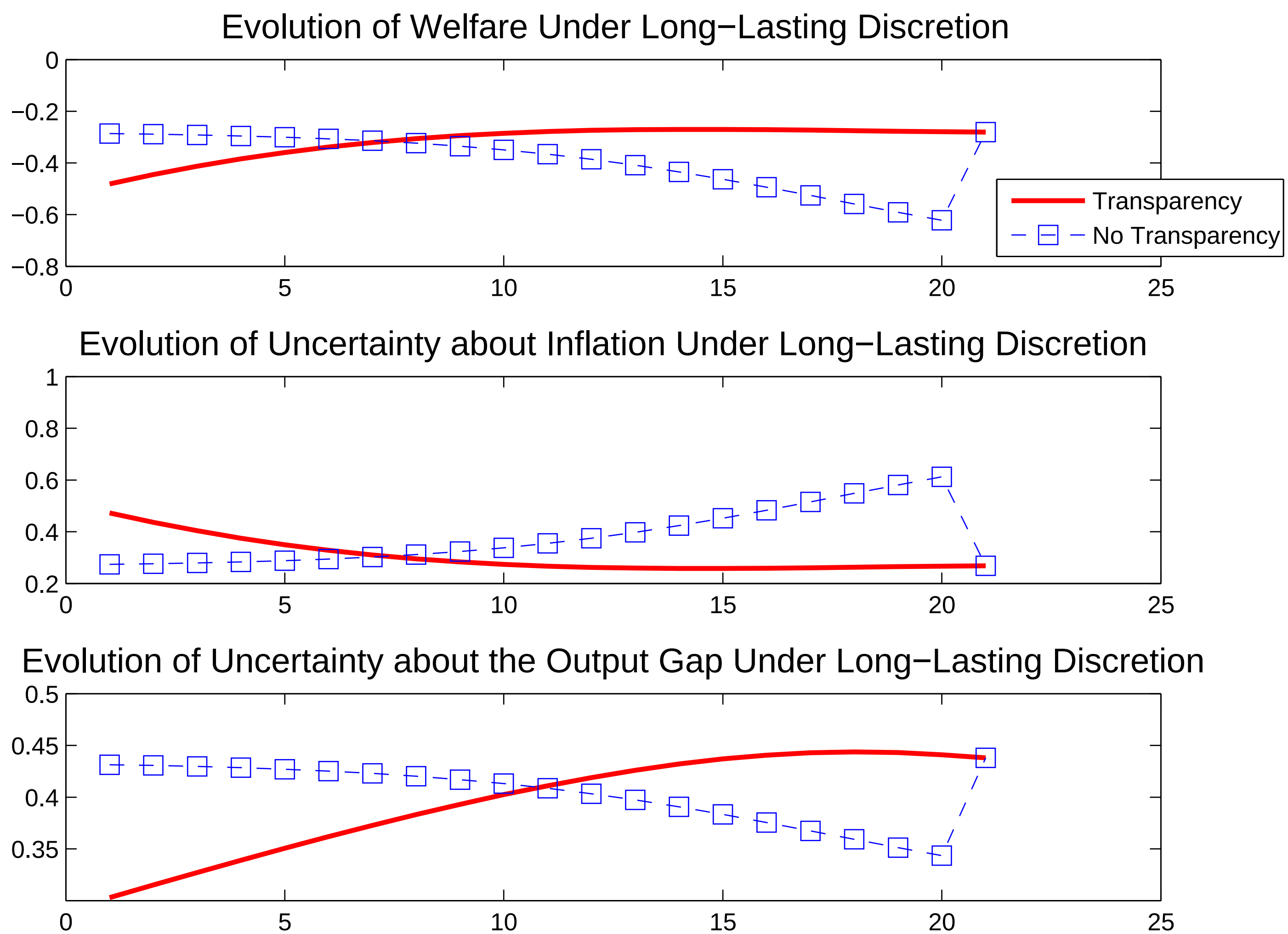

Figure 4: Evolution of Welfare as the Discretionary Policy is Implemented: The Case of Long-Lasting Discretion and Strong Commitment

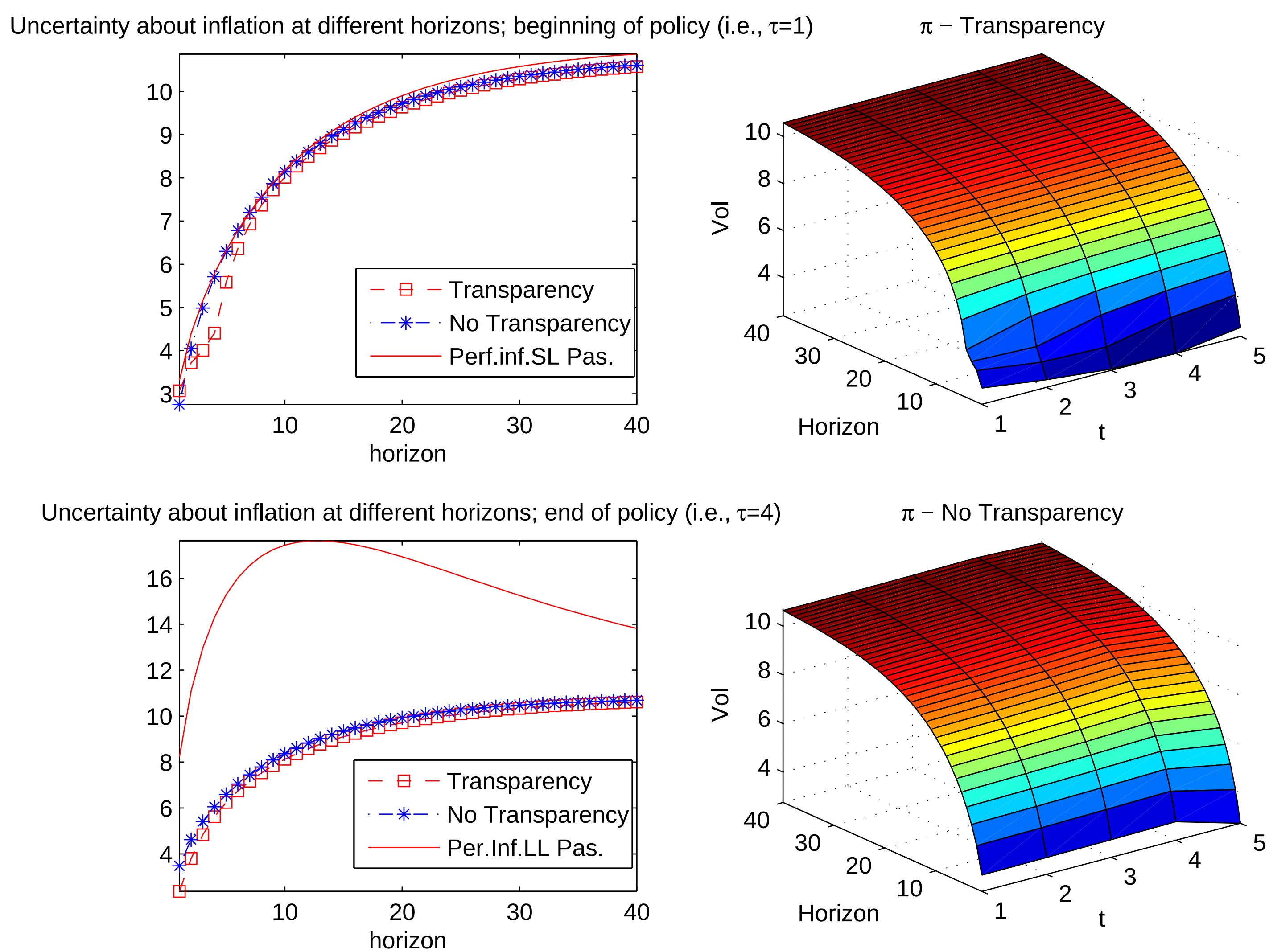

Figure 5: Evolution of Uncertainty: The Case of Short-Lasting Discretion and Strong Commitment

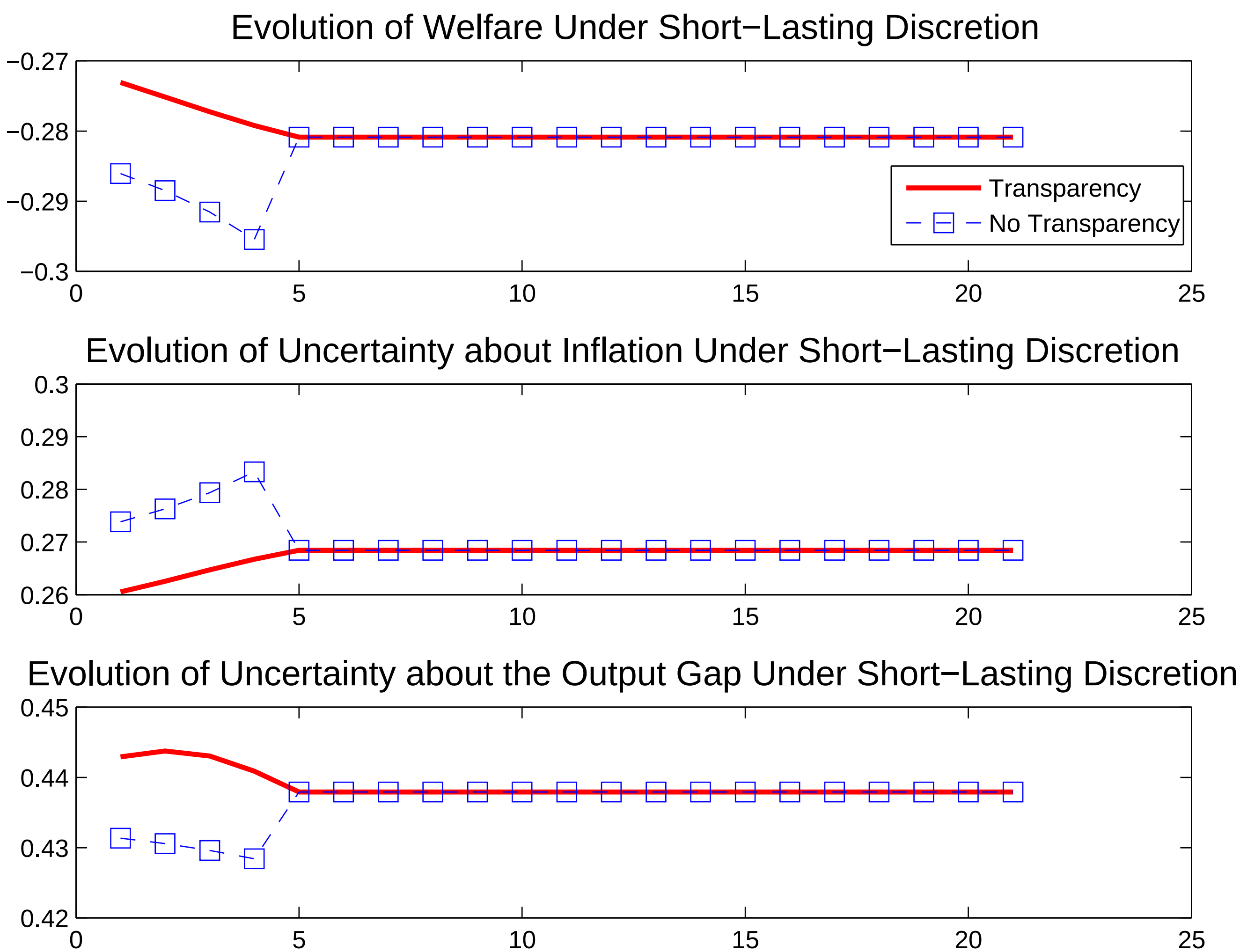

Figure 6: Evolution of Welfare as the Discretionary Policy is Implemented: The Case of Short-Lasting Discretion and Strong Commitment

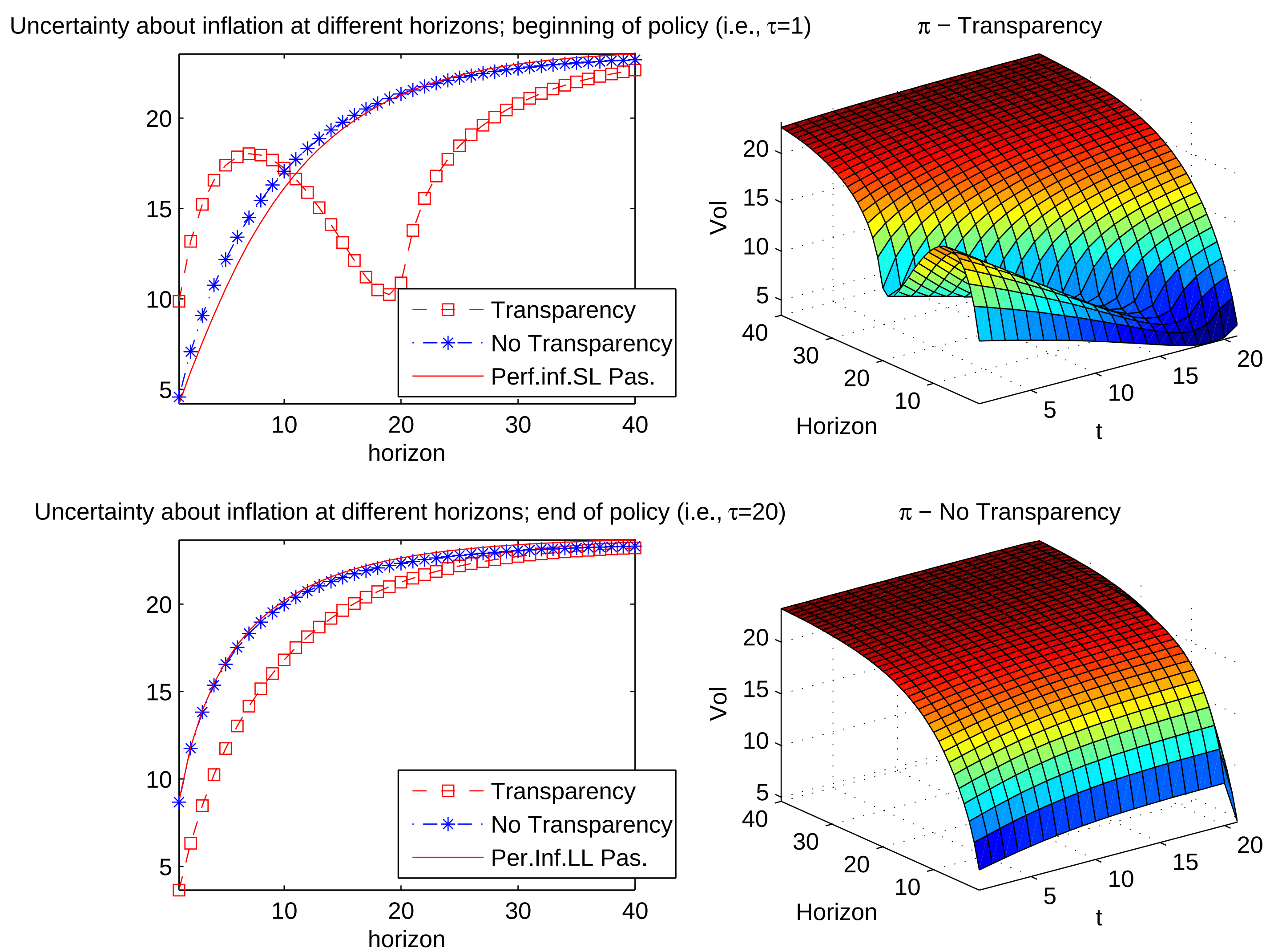

Figure 7: Evolution of Uncertainty: The Case of Long-Lasting Discretion and Weaker Commitment

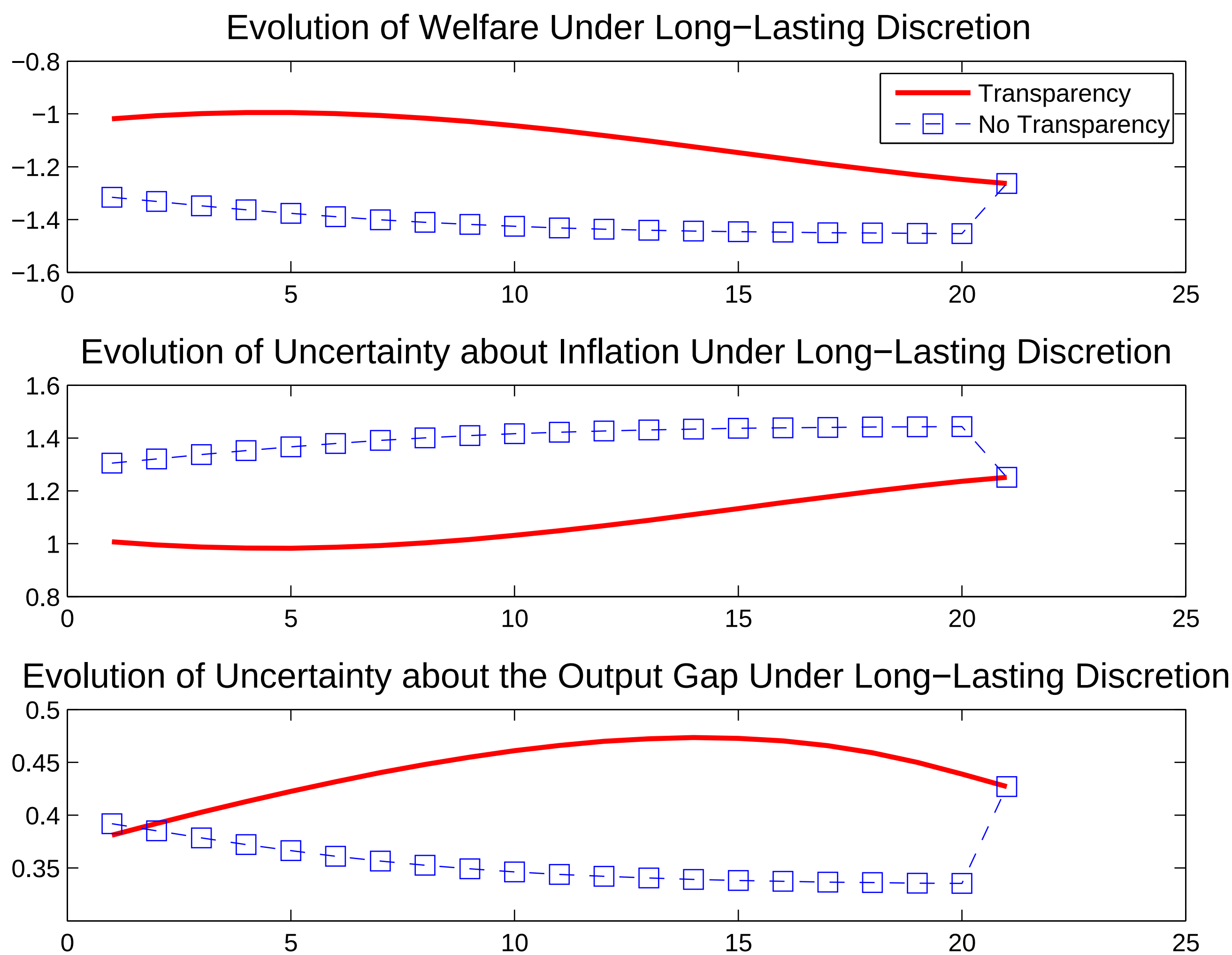

Figure 8: Evolution of Welfare as the Discretionary Policy is Implemented: The Case of Long-Lasting Discretion and Weaker Commitment

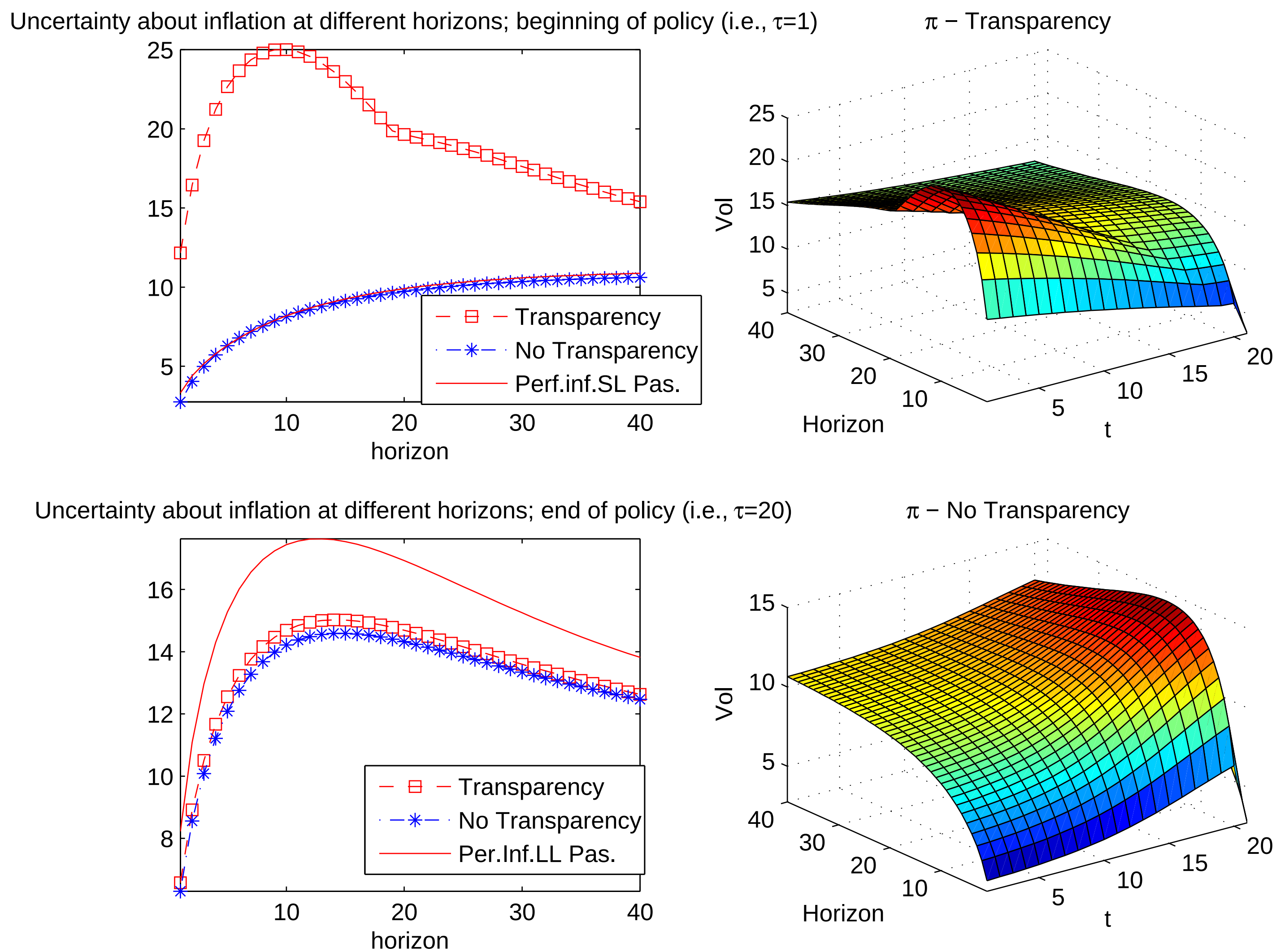

Figure 9: Evolution of Uncertainty: The Case of Long-Lasting Discretion, Strong Commitment, and Non-Credible Announcements

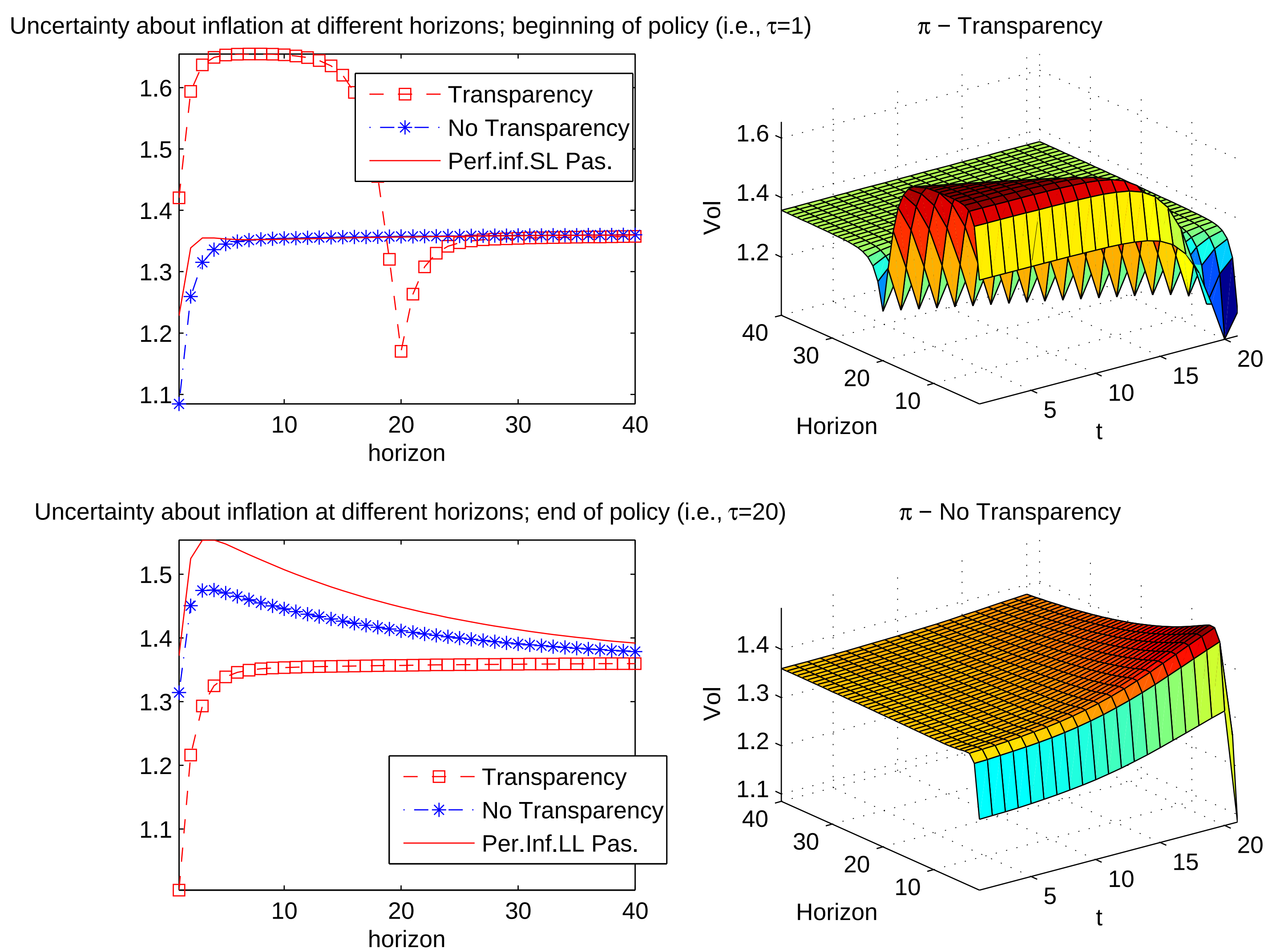

Figure 10: Evolution of Uncertainty: The Case of Long-Lasting Discretion, Strong Commitment, and Lower Persistence

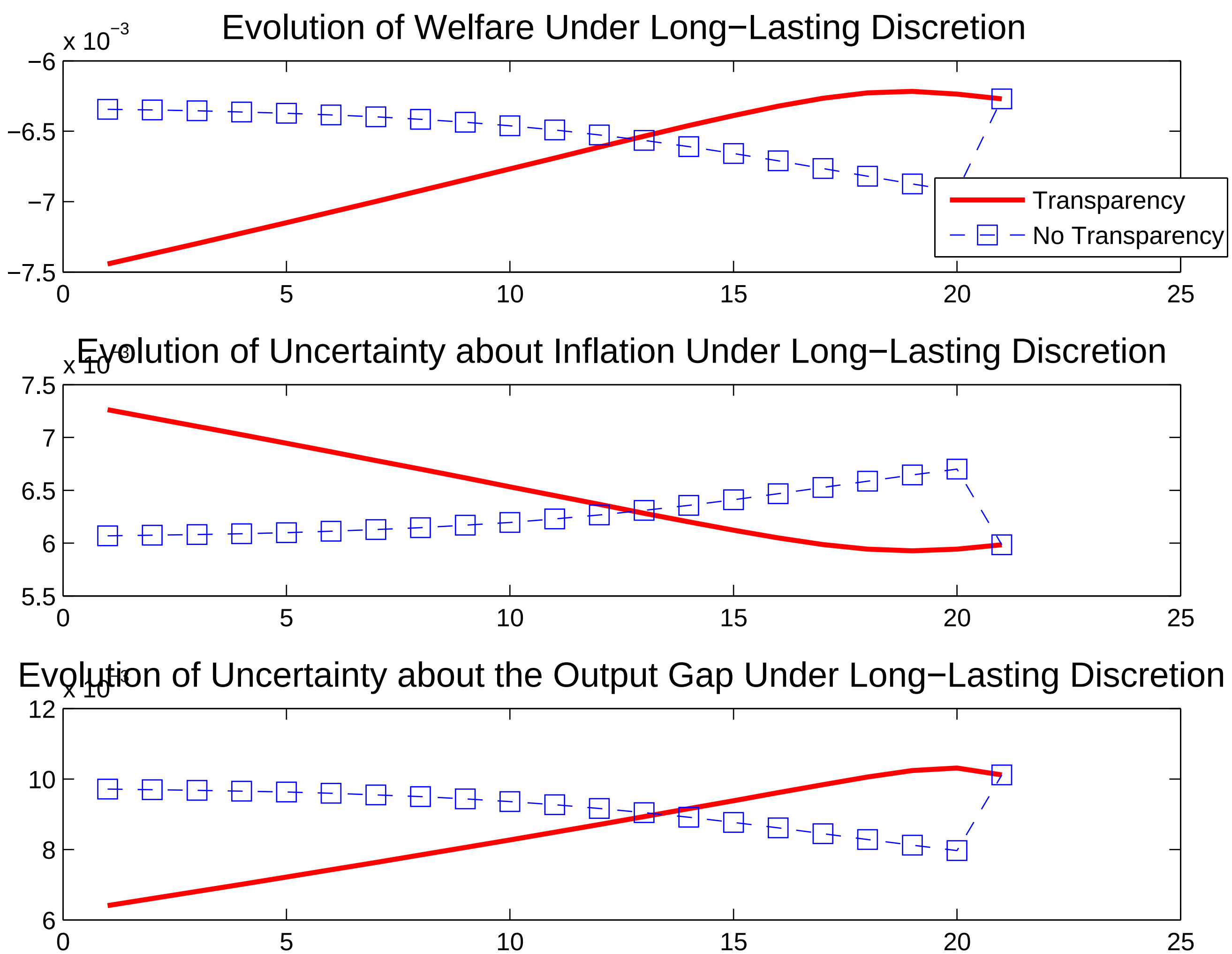

Figure 11: Evolution of Welfare as the Discretionary Policy is Implemented: The Case of Long-Lasting Discretion, Strong Commitment, and Lower Persistence

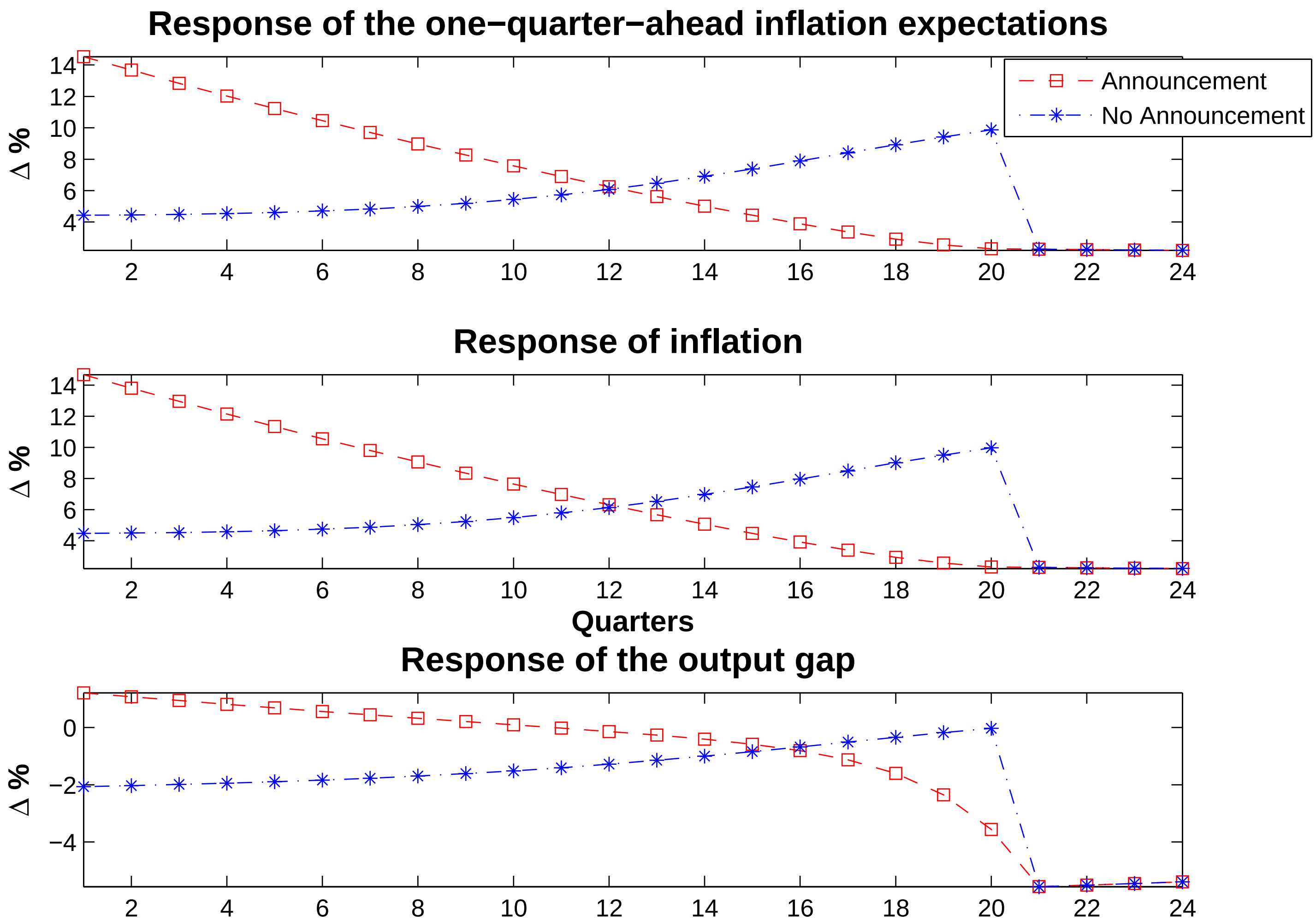

Figure 12: Impulse Response Functions: The Case of Long-Lasting Discretion and Strong Commitment

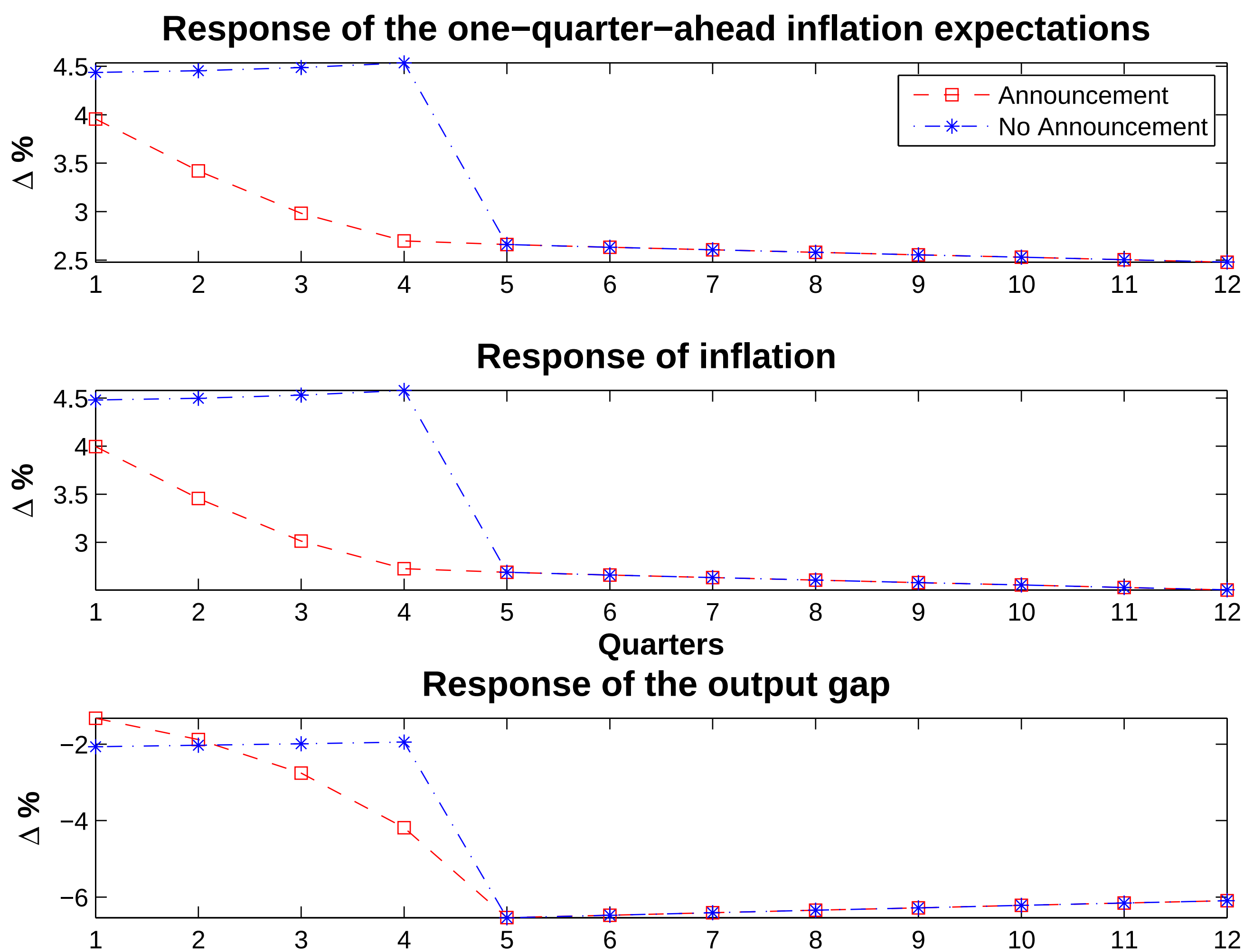

Figure 13: Impulse Response Functions: The Case of Short-Lasting Discretion and Strong Commitment

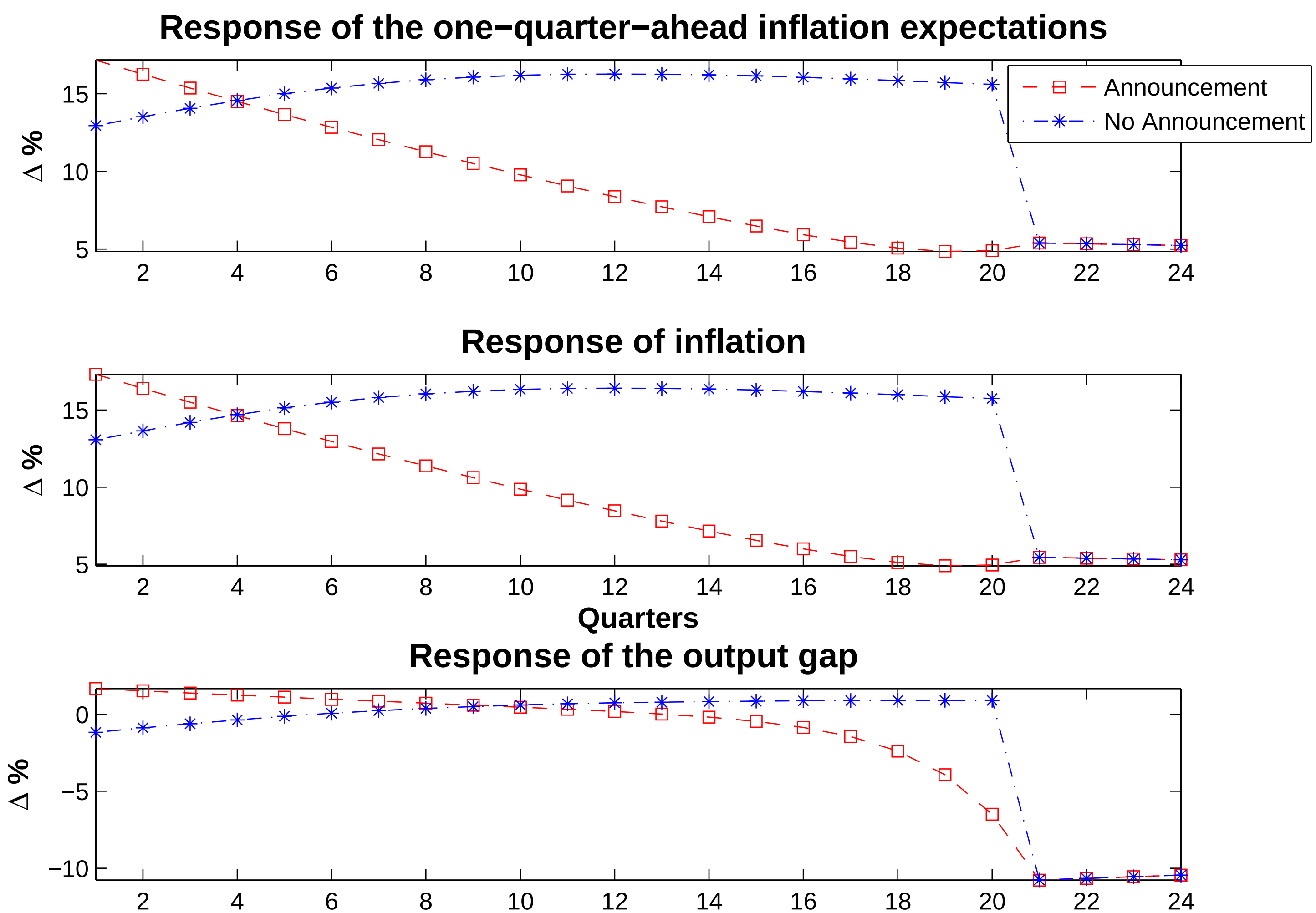

Figure 14: Impulse Response Functions: The Case of Long-Lasting Discretion and Weaker Commitment

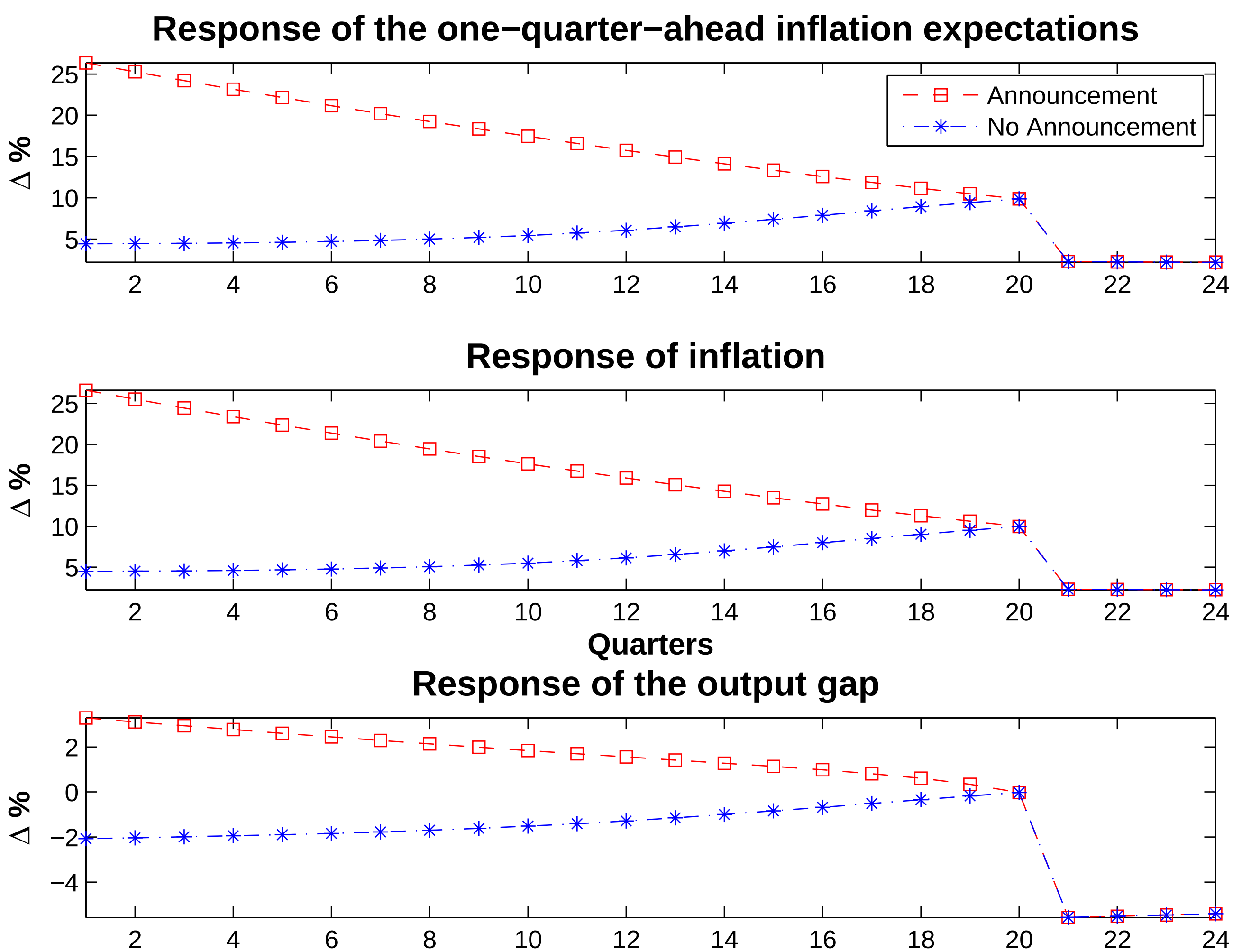

Figure 15: Impulse Response Functions: The Case of Long-Lasting Discretion, Strong Commitment, and Non-Credible Announcements