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# "Constrained Discretion and Central Bank Transparency"

by

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# Constrained Discretion and Central Bank Transparency

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**Abstract**

We develop a theoretical framework to quantitatively assess the general equilibrium effects and welfare implications of central bank reputation and transparency. Monetary policy alternates between periods of active inflation stabilization and periods during which the emphasis on inflation stabilization is reduced. When the central bank only engages in short deviations from active monetary policy, inflation expectations remain anchored and the model captures the monetary approach described as *constrained discretion*. However, if the central bank deviates for a prolonged period of time, agents gradually become pessimistic about future monetary policy, the disanchoring of inflation expectations occurs, and uncertainty rises. Reputation determines the speed with which agents' pessimism accelerates once the central bank starts deviating. When the model is fitted to U.S. data, we find that the Federal Reserve can accomodate contractionary technology shocks for up to five years before inflation expectations take off. Increasing transparency would improve welfare by anchoring agents' expectations. Gains from transparency are even more sizeable for countries whose central banks have weak reputation.

**Keywords:** Bayesian learning, reputation, uncertainty, inflation expectations, Markov-switching models, impulse response.

*JEL classification: E52, D83, C11.*

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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) explains that under constrained discretion, the central bank retains some flexibility in the conduct of monetary policy in order to accommodate short run disturbances. However, such flexibility is constrained to the extent that the central bank should maintain a strong reputation for keeping inflation and inflation expectations firmly under control. Second, many countries have taken remarkable steps to make their central banks more transparent (Bernanke et al., 1999 and Mishkin 2001). As a result of these changes, some key questions lie at the heart of modern monetary policy making. First, for how long can a central bank de-emphasize inflation stabilization before the private sector starts fearing a return to a period of high and volatile inflation as in '70s? Second, does transparency play an essential role for effective monetary policy making? In other words, should a central bank be explicit about the future course of monetary policy?

The recent financial crisis has triggered a prolonged period of accommodative monetary policy that some members of the Federal Open Market Committee fear could lead to a disanchoring of inflation expectations.[1] As a result, the research questions outlined above are at the center of the policy debate. In order to address them, this paper develops a new theoretical framework to quantitatively assess the role of central bank reputation and transparency for modern monetary policy making. We model an economy in which the anti-inflationary stance of the central bank can change over time. When monetary policy alternates between prolonged periods of active inflation stabilization, *active regime*, and short periods during which the emphasis on inflation stabilization is reduced, *short-lasting passive regime*, the model captures the monetary approach described as constrained discretion. However, the central bank can also decide to engage in a prolonged deviation from the active regime and move to a *long-lasting passive regime.* Agents in the model are fully rational and able to infer if monetary policy is active or not. However, when the passive rule prevails, they are uncertain about the nature of the observed deviation. In other words, agents are not sure if the central bank is engaging in a short or long-lasting deviation from the active regime. The central bank can then follow two possible communication strategies: *Transparency* and *no transparency.* Under no transparency, the nature of the deviation is not revealed. Under transparency, the duration of any deviation is announced.

Under no transparency, when passive monetary policy prevails, agents conduct Bayesian

[1] As an example see Plosser (2012).

learning in order to infer the likely duration of the deviation from active monetary policy. Given that the behavior of the monetary authority is unchanged across the two passive regimes, the only way for agents to learn about the nature of the deviation consists of keeping track of the number of consecutive deviations. As agents observe more and more realizations of the passive rule, they become increasingly convinced that the long-lasting passive regime is occurring. As a result, the more the central bank deviates from active inflation stabilization, the more agents become pessimistic about a quick return to the active regime.

The ability of generating waves of pessimism in response to central bank actions makes the model an ideal laboratory to study the macroeconomic and welfare implications of constrained discretion. In the model, welfare is a function of inflation and output gap volatilities. Both measures of uncertainty keep increasing as agents become more pessimistic about the future conduct of monetary policy. In standard models, monetary policy affects agents' welfare by influencing the unconditional variances of the endogenous variables. In our setting, policy actions exert dynamic effects on uncertainty. Therefore, welfare evolves over time in response to the short-run fluctuations of uncertainty. To our knowledge, this feature is new in the literature.

We measure uncertainty 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 agents regard the early deviations as temporary. However, as the number of deviations increases and fairly optimistic agents become fairly pessimistic, uncertainty starts increasing and eventually converges to the values implied by the long-lasting passive regime. As a result, for each horizon, our measure of uncertainty is now higher than the ergodic long run volatility. This is because agents take into account that while in the short run a prolonged period of passive monetary policy will prevail, in the long run the economy will surely visit the active regime again. Therefore, an important result arises: Deviations from the active regime that last only a few periods have no disruptive consequences on welfare because they do not have a large impact on agents' uncertainty regarding future monetary policy. Instead, if a central bank deviates for a prolonged period of time, the disanchoring of agents' expectations occurs, causing sizeable welfare losses.

In order to put discipline on the parameter values, the model under the assumption of no transparency is fitted to U.S. data. The results are then used to investigate how strong the Federal Reserve reputation is and to quantify the gains from transparency. The paper introduces a practical definition of reputation: a central bank has strong reputation if it is less likely to engage in long-lasting deviations from active policies. It is worth pointing out that the proposed definition of central bank reputation is not only reflected in the in sample frequency of regime changes, but it also manifests itself affecting agents' beliefs and, consequently, the general equilibrium properties of the macroeconomy. Therefore, the proposed definition of central bank reputation has the advantage of being measurable in the data, while at the same time being in line with the seminal contributions of Kydland and Prescott (1977), Barro and Gordon (1983), and Gali and Gertler (2007).

The Federal Reserve is found to benefit from strong reputation. Based on the estimates, pessimism and hence inflation expectations change very sluggishly in response to deviations from active monetary policy. In fact, following an inflationary technology slowdown that the Federal Reserve decides to accommodate deviating from active monetary policy, inflation expectations and inflation are found to move very slowly during the first five years of the deviation. However, if monetary policy remains accommodative after the first five years, inflation expectations and inflation rapidly accelerate. This finding has two important implications. First, under no transparency, the model predicts that inflation drifts up for several years after a technology slowdown. Second, the Federal Reserve can conduct accommodative policies for up to five years before the *constraint* over *discretion* becomes binding.

While this result implies that the Federal Reserve can successfully implement constrained discretion even without transparency, our findings suggest that increasing transparency would improve welfare. A transparent central bank systematically announces the duration of any deviation from the active regime beforehand. This has a twofold effect on welfare. First, in the short run welfare declines because agents have been told that passive monetary policy will prevail for a while and thereby future shocks are expected to have more dramatic inflationary/deflationary consequences. It follows that, if the duration of the announced deviation is long enough, over the early periods uncertainty is higher than when no announcement is made. Second, as time goes by, 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, transparency pegs pessimism down, preventing a quick deterioration of welfare.

In general, which one of the two effects prevails depends on central bank reputation that, in turn, controls how quickly inflation expectations and uncertainty take off in absence of central bank transparency. If reputation is weak, agents will interpret the first observed deviation as a switch to the long-lasting regime, leading to a strong and sudden rise of pessimism about future monetary policy and a fast deterioration in welfare. Therefore, the actual leeway in de-emphasizing inflation stabilization might be rather limited for those central banks that have failed establishing a strong reputation. Consequently, while still beneficial for the U.S., transparency is even more desirable for central banks with weak reputation because it helps in anchoring pessimism and uncertainty. This prediction of the model provides an explanation for why since the 1990s, many countries whose central banks could not develop a strong reputation, have reformed their monetary policy strategy with the goal of enhancing transparency (Bernanke et al., 1999 and Mishkin 2001).[2]

As an important *caveat*, we show that the choice of establishing a transparent central bank must be associated with an increase in accountability meant to guarantee that central bank announcements are deemed credible. This last result squares well with the observation that the increase in central bank transparency is generally associated with institutional reforms that aim to make central banks more accountable for their announced policy objectives. The intuition behind the result goes as follows. Suppose that a central bank correctly reveals short-lasting deviations, but it never announces more than a certain number of consecutive periods of passive monetary policy. As a result, whenever a deviation is announced, agents will take into account that its effective duration might exceed what was communicated to the public. This leads to a welfare loss that can make transparency welfare reducing. Such an outcome is more likely if a central bank suffers from a weak reputation. In this case, the probability of a lie about the effective duration of a deviation increases because central banks with weak reputations are more likely to engage in long lasting deviations that would not be correctly announced.

The way in which transparency is modeled in this paper closely resembles the *forward guidance* about the future likely path of the policy interest rate, which the Federal Reserve has recently decided to re-introduce. Our results show that *forward guidance* improves welfare especially when monetary policy has to cope with highly persistent shocks, such as the ones that have determined the current financial crisis. Cambell, Evans, Fisher, and Justiniano (2012) also study the macroeconomic effects of *forward guidance*. Unlike our approach, that paper models *forward guidance* by means of anticipated monetary shocks.

Our work is also linked to papers that study the impact of monetary policy decisions on inflation expectations, such as Nimark (2008), Mankiw, Reis, and Wolfers (2004), Del Negro and Eusepi (2010), and Melosi (2012). 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 only have incomplete information. Cogley, Matthes, and Sbordone (2011) address the problem of a newly-appointed central bank governor who inherits a high average inflation

[2] More specifically, many countries (e.g., UK, Chile, Brazil, Poland, and New Zealand) have adopted a monetary policy framework that goes under the name of *inflation targeting*.

rate from the past and wants to disinflate. In their model, agents conduct Bayesian learning over the coefficients that characterize the conduct of monetary policy. In our framework, agents learn about the regime that is in place. This modeling choice allows us to introduce agents that *know that they do not know*: They form expectations taking into account that their beliefs will change according to what they will observe in the future. This approach is substantially different from the anticipated utility assumption traditionally used in the learning literature.

To the best of our knowledge, this paper represents the first attempt to estimate a general equilibrium model with Markov-switching regime changes and learning. To solve the model we rely on the methods developed in Bianchi and Melosi (2012). 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), Benati and Surico (2009), Bianchi (2010), Davig and Doh (2008), and Fernï£¡ndez-Villaverde and Rubio-Ramï£¡rez (2008) introduce parameter instability in dynamic equilibrium models, while Sims and Zha (2006), Primiceri (2005), Cogley and Sargent (2005), and Boivin and Giannoni (2006) work with structural VARs.

This paper is organized as follows. Section 2 introduces the baseline model. In Section 3 we define and discuss the notion of transparency used in the paper. In Section 4, the model under the assumption of no transparency is fitted to U.S. data. Section 5 studies the macroeconomic effects of passive policies with and without transparency. In Section 6 we use the estimated model to assess the welfare implication of introducing transparency. In Section 7, we deal with two extensions: (*i*) a central bank with a weaker reputation than that of the Federal Reserve and (*ii*) a transparent central bank that can make only partially credible announcements. Section 8 concludes.

# 2 A Prototypical DSGE Model

The model is a prototypical three-equation New-Keynesian model (Clarida, Gali, and Gertler, 2000 and Woodford, 2003), which has been used for empirical studies (Lubik and Schorfheide, 2004). We make two main departures from this standard framework. First, we assume that agents (i.e., households and firms) have incomplete information, in a sense to be made clear shortly. Second, we assume parameter instability in the monetary policy rule.

**Households:** The representative household maximizes

$$E\left[\sum_{t=0}^{\infty}\beta^t G_t\left((1-\sigma)^{-1}C_t^{1-\sigma}-\chi\left(1+\psi\right)^{-1}N_t^{1+\psi}\right)|\mathcal{F}_0\right],$$

where $C_t$ is composite consumption and $N_t$ are hours worked in period $t$. The parameter $\beta \in (0,1)$ is the discount factor, the parameter $\psi \geq 0$ is the inverse of the Frisch elasticity of labor supply, and the parameter $\chi > 0$ affects the disutility of supplying labor. $E\left[\cdot|\mathcal{F}_0\right]$ is the expectation operator conditioned on information of private agents (i.e., households and firms) available at time 0. The information set $\mathcal{F}_t$ contains the history of all model variables but not the history of monetary regimes that determine the parameter value of the central bank's reaction function. $G_t$ is an intertemporal preference shock, which is assumed to follow a stationary first-order autoregressive process:

$$\ln G_t = \rho_g \ln G_{t-1} + \sigma_g \varepsilon_{gt},\ \ \varepsilon_{gt} \sim N\left(0,1\right). \tag{1}$$

Composite consumption in period $t$ is given by the Dixit-Stiglitz aggregator

$$C_t = \left(\int_0^1 C_{it}^{1-1/\varepsilon} di\right)^{\frac{\varepsilon}{\varepsilon-1}},$$

where $C_{it}$ is consumption of a differentiated good $i$ in period $t$. The variable $\varepsilon$ affects the elasticity of substitution between consumption goods. The flow budget constraint of the representative household in period $t$ reads

$$P_t C_t + B_t = R_{t-1}B_{t-1} + W_t N_t + D_t - T_t,$$

where $P_t$ is the price level in period $t$, $B_{t-1}$ is the stock of one-period nominal government bonds held by the household between period $t-1$ and period $t$, $R_{t-1}$ is the gross nominal interest rate on those bonds, $W_t$ is the nominal wage rate, $D_t$ are nominal aggregate profits, and $T_t$ are nominal lump-sum taxes in period $t$. The price level is given by

$$P_t = \left(\int_0^1 P_{it}^{1-\varepsilon} di\right)^{1/(1-\varepsilon)}. \tag{2}$$

In every period $t$, the representative household chooses a consumption vector, labor supply, and bond holdings subject to the sequence of the flow budget constraints and a no-Ponzi-scheme condition. The representative household takes as given the nominal interest rate, the nominal wage rate, nominal aggregate profits, nominal lump-sum taxes, and the prices of all consumption goods.

**Firms:** There is a continuum of monopolistically competitive firms of mass one. Firms are indexed by $i$. Firm $i$ supplies a differentiated good $i$. Firms face Calvo-type nominal rigidities and the probability of resetting prices in any given period is given by $1-\theta$ independent across firms. Firms that are allowed to reset their price choose their price $P_t^*(i)$ so as to maximize:

$$\sum_{k=0}^{\infty} \theta^t E_t \left[ Q_{t,t+k} \left( P_t^*(i) Y_{t+k}(i) - W_{t+k} N_{t+k}(i) \right) | \mathcal{F}_t \right]$$

where $Q_{t,t+k}$ is the stochastic discount factor measuring the time $t$ utility of one unit of consumption good available at time $t+k$, $N_t(i)$ is amount of labor hired, and $Y_t(i)$ is the amount of differentiated good produced by firm $i$. Firms are endowed with an identical technology of production:

$$Y_t(i) = Z_t N_t^{1-\alpha}(i).$$

The variable $Z_t$ captures exogenous shifts of the marginal costs of production and is assumed to follow a stationary first-order autoregressive process:

$$\ln Z_t = \rho_z \ln Z_{t-1} + \sigma_z \varepsilon_{zt}, \; \varepsilon_{zt} \sim N(0,1). \tag{3}$$

We refer to the innovation $\varepsilon_{zt}$ as a technology shock. Re-optimizing firms face a sequence of demand constraints:

$$Y_{t+k}(i) = \left( P_t^*(i) / P_{t+k} \right)^{-\varepsilon} Y_{t+k}$$

**Policy Makers:** There is a monetary authority and a fiscal authority. The flow budget constraint of the fiscal authority in period $t$ reads

$$T_t + B_t = R_{t-1} B_{t-1}.$$

The fiscal authority has to finance maturing government bonds. The fiscal authority can collect lump-sum taxes or issue new government bonds. We assume that the fiscal authority follows a Ricardian fiscal policy. The monetary authority sets the nominal interest rate $R_t$ according to the reaction function

$$R_t = \Pi_t^{\phi_\pi(s_t)} \left( Y_t / Y_t^* \right)^{\phi_y(s_t)} \exp\left( \sigma_r \varepsilon_{rt} \right), \; \varepsilon_{rt} \sim N(0,1) \tag{4}$$

where $\Pi_t = (P_t / P_{t-1})$ is inflation and $Y_t$ is aggregate output in period $t$, and $Y_t^*$ is the flexible-price output allocation. The variable $\varepsilon_{rt}$ captures non-systematic exogenous deviations of the nominal interest rate $r_t$ from the rule. We model changes in monetary policy by introducing a Markov-switching process $s_t$ with three regimes that evolve according to the matrix:

$$\mathcal{P}=\left[\begin{array}{ccc} p_{11} & p_{12} & p_{13} \\ 1-p_{22} & p_{22} & 0 \\ 1-p_{33} & 0 & p_{33} \end{array}\right] \tag{5}$$

The realized regime determines the monetary policy parameters of the central bank's reaction function. In symbols, for $i \in \{1,2,3\}$:

$$\left(\phi_\pi\left(s_t=i\right), \phi_y\left(s_t=i\right)\right)=\left[\begin{array}{c} \left(\phi_\pi^A, \phi_y^A\right), \text{ if } i=1 \\ \left(\phi_\pi^P, \phi_y^P\right), \text{ if } i=2 \\ \left(\phi_\pi^P, \phi_y^P\right), \text{ if } i=3 \end{array}\right] \tag{6}$$

Under Regime 1, the *active regime*, the central bank's main goal is to stabilize inflation and the Taylor principle is satisfied $\phi_\pi\left(s_t=1\right)=\phi_\pi^A \geq 1$. Under Regime 2, the *short-lasting passive regime*, the central bank de-emphasizes inflation stabilization and deviates from the Taylor principle $\phi_\pi\left(s_t=2\right)=\phi_\pi^P<\phi_\pi^A$, but only for short periods of time. The same parameter combination also characterizes Regime 3, the *long-lasting passive regime*, $\phi_\pi\left(s_t=3\right)=\phi_\pi^P<\phi_\pi^A$. However, under Regime 3 deviations are generally more prolonged. In other words, Regime 2 is substantially less persistent than Regime 3: $p_{22}<p_{33}$. Summarizing, the two passive regimes do not differ in terms of the response to inflation $\phi_\pi^P$ and the output gap $\phi_y^P$, but only in terms of their persistence.

This way of modeling central bank behavior allows us to study two alternative approaches to monetary policy that the empirical literature has found to govern U.S. monetary policy from the 1960s on. The first approach has been labeled *constrained discretion* and it has arguably characterized U.S. monetary policy from the early 1980s on. Under this approach the central bank is mainly focused on stabilizing inflation and inflation expectations but sometimes it conducts short-lasting passive policies that de-emphasize inflation stabilization in favor of alternative objectives, such as output-gap stabilization. Under the second approach, the central bank de-emphasizes inflation stabilization for a very long period of time. According to some authors, the second approach has mainly characterized U.S. monetary policy in the late 1960s and in the 1970s (Clarida, Gali, and Gertler, 2000, Lubik and Schorfheide, 2004, Bianchi, Forthcoming).

The probabilities $p_{11}$, $p_{12}$, $p_{22}$ govern the evolution of monetary policy when the central bank follows constrained discretion. The larger $p_{12}$ is vis-a-vis to $p_{11}$, the more frequent the short-lasting deviations are. The larger $p_{22}$ is, the more persistent the short-lasting deviations are. The probability $p_{13}$ controls how likely it is that constrained discretion is abandoned in favor of a prolonged deviation from the active regime. Therefore, the relative probability of a short-lasting deviation with respect to the overall probability of a deviation (i.e., $p_{12}/(1-p_{11})$) captures central bank *reputation*. This composite parameter controls how likely it is that the central bank will abandon constrained discretion the moment it starts deviating from the active regime. As it will become clear later on, central bank reputation has deep implications for the general equilibrium properties of the macroeconomy. Therefore, the parameters of the transition matrix do not only affect the frequency with which the different regimes are observed, but also the law of motion of the model across the different regimes. This is because agents are fully rational and form expectations taking into account the possibility of regime changes. Therefore, the proposed definition of central bank reputation has the important advantage of being measurable, even over a relatively short period of time.

# 3 Communication Strategies and Solution

We log-linearize the model around the (unique) zero-inflation steady-state equilibrium. Following Lubik and Schorfheide (2004) we redefine the preference process $G_t$ and obtain:

$$y_t = \mathbb{E}(y_{t+1}|\mathcal{F}_t) - \sigma^{-1}[i_t - \mathbb{E}_t(\pi_{t+1}|\mathcal{F}_t)] + g_t \tag{7}$$

$$\pi_t = \beta\mathbb{E}_t(\pi_{t+1}|\mathcal{F}_t) + \kappa(y_t - z_t) \tag{8}$$

$$r_t = \phi_\pi(s_t)\pi_t + \phi_y(s_t)(y_t - z_t) + \varepsilon_{r,t} \tag{9}$$

$$g_t = \rho_g g_{t-1} + \sigma_g\varepsilon_{gt} \tag{10}$$

$$z_t = \rho_z z_{t-1} + \sigma_z\varepsilon_{zt} \tag{11}$$

where lowercase variables denote deviations of uppercase variables from their steady state equilibrium.

We assume that whenever the central bank deviates from the active regime, it is aware of the duration of the deviation. The model can then be solved under different assumptions on what the central bank communicates to agents about the future monetary policy course. Central bank communication affects agents' information set $\mathcal{F}_t$. We consider two cases: *transparency* and *no transparency*.

Under *transparency* all the information held by the central bank is communicated to agents. Given the assumption that the central bank knows the number of periods in which monetary policy will be passive, a transparent central bank announces the duration of passive policies, revealing to agents exactly *when* monetary policy will switch back to the active regime. It is important to emphasize that agents form their beliefs by taking into account that the central bank will *systematically* announce the duration of passive policy. First, we analyze the case in which central bank announcements are deemed as fully credible. Later, we will relax this assumption. Appendix A provides details on how to solve the model under the assumption of transparency.

If the central bank is not transparent, it never announces the duration of passive policies. We call this approach *no transparency*. We make a minimal departure from the assumption of perfect information assuming that agents can observe the history of all the endogenous variables as well as the history of the structural shocks, but not the regimes themselves (i.e., they do not observe $s_t$). Therefore, agents are always able to infer if monetary policy is currently active or passive. However, when monetary policy is passive, agents cannot immediately figure out whether the short-lasting Regime 2 or the long-lasting Regime 3 is in place. To see why, recall that the two passive regimes are observationally equivalent to agents, given that $\phi_\pi^p$ and $\phi_y^p$ are the same across the two regimes. Therefore, agents conduct Bayesian learning in order to infer which one of the two regimes is in place. In the next section we will discuss how agents' beliefs evolve as agents observe more and more deviations from the active regime. The details on how to solve the model under no transparency are described in Bianchi and Melosi (2012b and Forthcoming).[3]

# 4 Empirical Analysis

In order to put discipline on the parameter values, the model under the assumption of no transparency is fitted to US data. We believe that this is the model that is better suited to capture the Federal Reserve communication strategy in our sample that ranges from mid-1950s to prior the great recession. We then use the results to quantify the Federal Reserve reputation and the potential gains from making the Federal Reserve more transparent.

Section 4 is organized as follows. Section 4.1 briefly deals with the Bayesian estimation of the model. In Section 4.2 we show the evolution of agents' pessimism about future monetary policy. The evolution of pessimism turns out to be key to understand the macroeconomic effects and the welfare implications of transparency.

[3]It might be argued that the central bank could try to signal the kind of deviation perturbing the Taylor rule parameters across the two rules. For example, $\phi_\pi (s_t = 3) = \phi_\pi (s_t = 2) + \xi$ for $\xi > 0$ and small. However, the point of the paper is exactly to capture agents' uncertainty about the duration of passive policies. Therefore, the model would be extended to allow for a total of four passive regimes: a long-lasting Regime 4 in which $\phi_\pi = \phi_\pi (s_t = 2)$ and $p_{44} > p_{22}$ and a short-lasting Regime 5 in which $\phi_\pi = \phi_\pi (s_t = 3)$ and $p_{55} < p_{33}$.

## 4.1 Data and Estimation

For observables, we use three series of U.S. quarterly data: the (HP filtered) real GDP per capita, the (demeaned) annualized quarterly inflation, and the Federal Funds Rate (FFR). The sample spans from 1954:III to 2008:I. Table 1 reports the prior and the posterior distribution of model parameters. For a detailed discussion of the estimation strategy see Bianchi (Forthcoming).

| | Posterior | | | Prior | | |
|---|---|---|---|---|---|---|
| Name | Mean | 5% | 95% | Type | Mean | Std. |
| $\phi_\pi^a$ | 2.5347 | 2.1877 | 2.9476 | $N$ | 1.7 | 0.8 |
| $\phi_y^a$ | 0.1055 | 0.0465 | 0.1717 | $G$ | 0.25 | 0.15 |
| $\phi_\pi^p$ | 0.9310 | 0.8710 | 0.9894 | $N$ | 0.8 | 0.4 |
| $\phi_y^p$ | 0.0199 | 0.0067 | 0.0379 | $G$ | 0.25 | 0.15 |
| $\tau$ | 2.2058 | 1.5670 | 2.9214 | $G$ | 2 | 0.5 |
| $\kappa$ | 0.0216 | 0.0157 | 0.0283 | $G$ | 0.5 | 0.2 |
| $\rho_g$ | 0.8511 | 0.8096 | 0.8871 | $B$ | 0.8 | 0.1 |
| $\rho_z$ | 0.9811 | 0.9666 | 0.9929 | $B$ | 0.7 | 0.15 |
| $R^*$ | 0.2593 | 0.2002 | 0.3193 | $G$ | 0.6 | 0.3 |
| $100\sigma_r$ | 0.0733 | 0.0586 | 0.0895 | $IG$ | 0.31 | 0.4 |
| $100\sigma_g$ | 0.1668 | 0.1310 | 0.2031 | $IG$ | 0.38 | 0.4 |
| $100\sigma_z$ | 0.488 | 0.4173 | 0.5639 | $IG$ | 1.0 | 0.8 |
| $100\sigma_\pi$ | 0.3958 | 0.3648 | 0.4273 | $IG$ | 0.15 | 0.3 |
| $p_{11}$ | 0.9675 | 0.9422 | 0.9870 | $B$ | 0.95 | 0.025 |
| $p_{22}/p_{33}$ | 0.8927 | 0.8386 | 0.9382 | $B$ | 0.7 | 0.1 |
| $p_{33}$ | 0.9849 | 0.9758 | 0.9931 | $B$ | 0.95 | 0.025 |
| $\frac{p_{12}}{1-p_{11}}$ | 0.9729 | 0.9437 | 0.9918 | $B$ | 0.95 | 0.025 |

Table 1: Prior and posterior statistics for the model parameters

The parameter $R^*$ denotes the steady-state real interest rate. The parameter $\sigma_\pi$ is the standard deviation of the measurement error associated with inflation. The elasticity of substitution between goods $\varepsilon$ cannot be identified because it drops out after log-linearizing the model. Following Gali (2008), we set this parameter value to 6, implying a mark-up of 20%. This parameter is important to quantify the welfare implications of transparency. Our results are robust to realistic variations in the value of $\varepsilon$.

The probability of being in the short-lasting passive regime conditional on having switched to passive policies, $p_{12}/(1-p_{11})$, plays a critical rule in the model. This parameter captures the frequency of the deviations to the short-lasting passive regime relative to the long-lasting one. As noticed in Section 2, the estimated value for this parameter sheds light on the strength of the Federal Reserve *reputation* to refrain from long-lasting deviations. We find that this parameter is estimated very close to one, suggesting that the Federal Reserve benefits from strong reputation.

## 4.2 Evolution of Pessimism

Monetary policy decisions on stabilizing inflation and communication strategies critically affect the social welfare and the macroeconomic equilibrium by influencing agents' pessimism about future monetary policy. We measure pessimism by computing the *expected* number of consecutive periods of passive monetary policy. To illustrate the effects of communication on pessimism, let us assume that the central bank decides to engage in passive policies for forty consecutive quarters. Figure 1 reports the evolution of pessimism under no transparency (dashed line) and under transparency (solid line with circles). For the case of no transparency the figure also includes the 60% credible intervals reflecting the uncertainty around the transition matrix. Under no transparency, as agents observe the first deviations, they are inclined to believe that the Federal Reserve is engaging in a short-lasting deviation. Therefore, agents remain quite optimistic and expect a switch to the active policy within two and half years. This is because short-lasting deviations from the active regime are conditionally more likely than the long-lasting ones, as discussed in Section 4.1. As agents observe more and more consecutive deviations, pessimism keeps increasing. However, it is important to note that pessimism dramatically accelerates only after twenty consecutive quarters of passive policy are observed. This result implies that the Federal Reserve can abandon inflation stabilization for quite a long time before agents become persuaded to have entered a prolonged period of passive monetary policy. Observing a few quarters of passive policy does not seem to substantially affect agents' beliefs about future monetary policy in the U.S.

Under transparency, pessimism follows an inverse path. Unlike the case of no transparency, agents' pessimism is very high at the initial stage of the deviation from the passive policy but it decreases as time goes by. As soon as the forty periods of passive monetary policy are announced, an immediate rise in pessimism occurs. As the number of periods of passive policy yet to be carried out decreases, agents' pessimism declines accordingly. At the end of the policy ($t = 40$), pessimism reaches its lowest level, with agents expecting to return to the active regime in the following period.

To sum up, Figure 1 allows us to isolate two important effects of transparency on agents' pessimism about future monetary policy: ($i$) *transparency raises pessimism at the beginning of the policy*; ($ii$) *transparency anchors down pessimism at the end of the policy.* As we shall show, these two effects play a critical role for both the macroeconomic effects and the welfare implications of transparency.

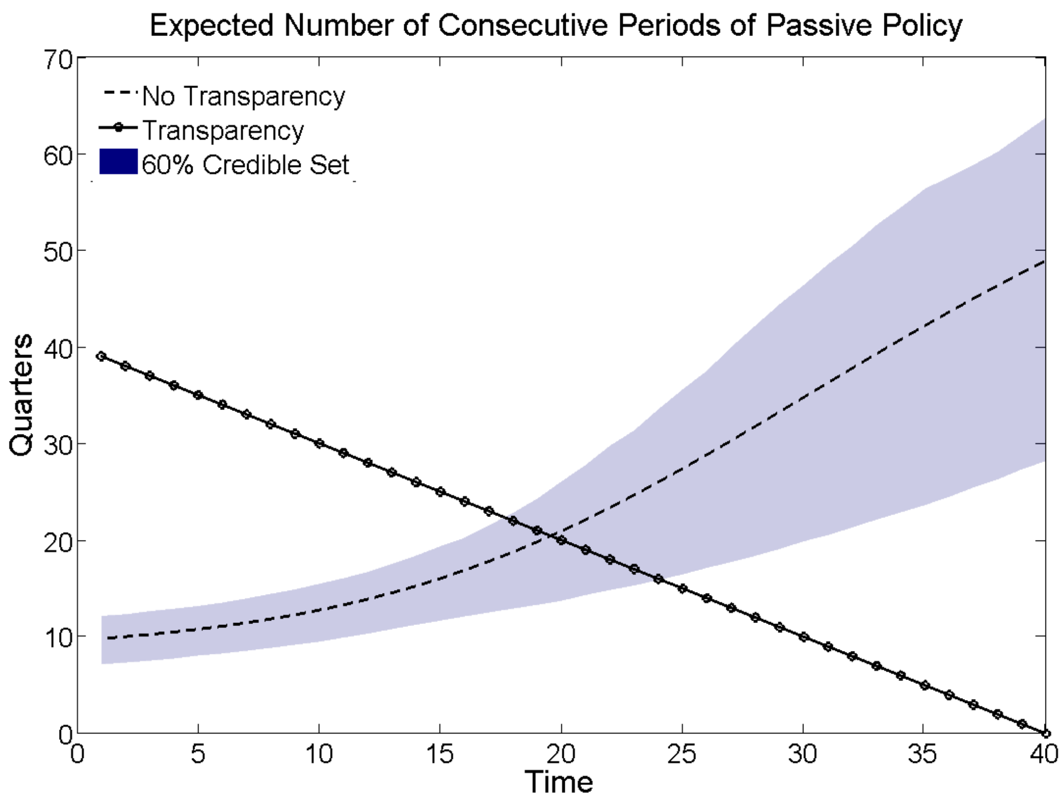


Figure 1: Evolution of Pessimism under "No Transparency" (the dashed line) and under "Transparency" (the line with circles). The figure reports the posterior mean of the expected number of periods of passive policy. The shaded area denotes 60-percent posterior credible intervals.

# 5 The Macroeconomic Effects of Transparency

Central banks are usually very concerned about how private sector inflation expectations react to short-run accommodative monetary policy. Constrained discretion is an effective way to conduct monetary policy only if the central bank can temporarily de-emphasize inflation stabilization and, at the same time, keep inflation and inflation expectations low and stable. Deviations that last too long are likely to raise concerns about the central bank commitment to low and stable inflation.

To illustrate how reputation and transparency affect the ability of the Federal Reserve to cope with inflationary shocks, Figure 2 shows the impulse response functions of inflation (right) and output (left) to a contractionary technology shock under transparency (upper plots) and no transparency (lower plots). We assume that as the shock hits the economy the central bank decides to ease monetary policy, performing forty quarters of consecutive deviations from active policy. Under no transparency, inflation remains stable for 20 quarters and then accelerates. At the last stages of the passive policy, inflation is clearly drifting. This drift is interrupted by the abrupt switch to active policy at time $t = 41$. Such a drift

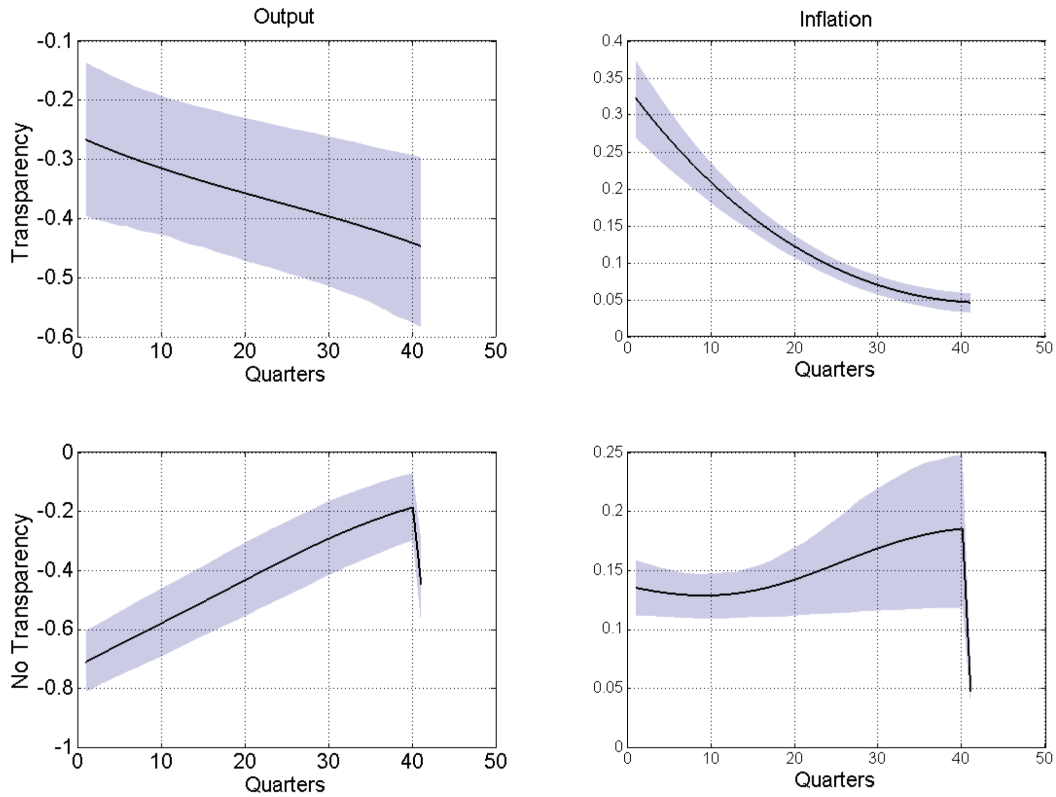


Figure 2: Impulse response functions of output (left column) and inflation (right column) to a two-standard-deviation technology shock. The lines are the posterior means. The shaded area denotes 60-percent posterior credible intervals. This responses are conditional on a policy path with two swicthes between regimes: 1) a swicth to the passive regime at time 1 (i.e., upon the shock); 2) a switch to the active regime at time 41.

in inflation in response to a technology shock is jointly explained by two important features of the estimated model: the persistence of the technology shock and the gradual rise of agents' pessimism about future monetary policy illustrated in Figure 1. The persistent, albeit declining, inflationary effects of the technology shock combine themselves with the fast rise in pessimism that occurs once the central bank has deviated for more than 4 or 5 years. After such a long-lasting passive policy agents become extremely discouraged about observing a prompt switch to active policy. As a result, they expect that the inflationary consequences of the technology shock that has hit the economy 5 years ago will be much more dramatic in the future. This explains why inflation trends up five years after the initial shock.

Summarizing, this exercise shows that in the aftermath of a contractionary technology shock the Federal Reserve can de-emphasize inflation stabilization for quite a long time before the *constraint on discretion* becomes binding. The model predicts that it takes nearly five years for the Federal Reserve to lose control over inflation. Transparency radically changes these results. This can be seen by comparing upper and lower plots of Figure 2. A first notable difference is that, under transparency, inflation does not drift upwards. The reason is linked to the fact that transparency anchors agents' expectations at the end of the deviation, as discussed in Section 4.2. Figure 1 shows that agents' pessimism is extremely small at the end of the announced policy because agents know that the central bank will soon return to the active regime. This feature reduces the inflationary consequences of persistent technology disturbances, preventing inflation from drifting upwards. The second notable difference consists of the fact that transparency magnifies the inflationary effect of shocks upon impact. Again, this has to do with the different pattern of pessimism under transparency and no transparency. As discussed in Section 4.2, *transparency raises pessimism at the beginning of the policy*. When the central bank announces a forty-quarter-long deviation from active policy to ease the contractionary effects of the technology shock, agents become suddenly more pessimistic and immediately expect higher inflation from the shock.

The left column of Figure 2 shows the impulse responses of output to the contractionary technology shock under transparency (upper plot) and no transparency (lower plot). It is worth emphasizing that under transparency output drifts down following a technology shock. At the beginning of the deviation, the announcement of a prolonged period of accommodative monetary policy mitigates the impact of the shock. As time goes by, agents can foresee the change from passive to active monetary policy approaching and this has a contractionary effect on output. Under no transparency, output follows a very different path. On impact, the economy experiences a large recession even if monetary policy is accommodative. This is because agents expect to revert to the active regime very soon. As agents become more and more convinced that monetary policy will stay passive for a long time, output keeps increasing. However, the moment the central bank moves back to the active regime, the economy experiences a contraction as agents revise expectations about future monetary policy.

To sum up, the model has three important predictions. First, in order to cope with a contractionary technology shock the Federal Reserve can engage in discretionary policies *lasting nearly five years* before losing control over inflation. Second, the lack of transparency exposes the economy to a run-up in inflation if technology shocks hit the economy. Third, if the central bank is interested in mitigating and smoothing the impact of an adverse technology shock on output, simply moving to the passive regime might not be enough because agents are likely to interpret the switch as temporary. Announcing a prolonged deviation would instead work, at the cost of an immediate increase in inflation.

# 6 Welfare Implications of Transparency

In this section, we use the model to assess the welfare implications of introducing transparency. The period welfare function is obtained by taking a log-quadratic approximation of the representative household's utility function (see Rotemberg and Woodford, 1999, Woodford, 2003 and Gali, 2008). It reads:

$$\mathbb{W}_i\left(\tau;\theta,\mathcal{P}\right)=-\textstyle\sum_{h=1}^{\infty}\beta^h\left[var_i\left(\pi_{t+h}|\tau\right)+\left(\kappa/\varepsilon\right)var_i\left(y_{t+h}-z_{t+h}|\tau\right)\right],\qquad i\in\{N,T\}\tag{12}$$

where $\theta$ is the parameter vector, $\mathcal{P}$ is the transition matrix, and $\tau$ denotes the observed duration of passive policy for the case of no transparency and the number of periods of announced passive policy yet to be carried out in the case of transparency. The subscript $i$ refers to the communication strategy: $i = N$ stands for the case of no transparency, while $i = T$ denotes transparency. This notation makes clear that welfare is evolving over time and depends on agents' pessimism, the structural parameters of the model, the frequency with which monetary policy deviates from the active regime, and the communication strategy. We analytically compute the stochastic variance taking into account regime uncertainty using the methods described in Bianchi (2011).

The output gap enters the welfare function because it reflects the difference between the marginal rate of substitution and the marginal product of labor, which is a measure of the economy's aggregate inefficiency (Woodford, 2003, Steinsson (2003), and Gali, 2008). Inflation deviations from its steady-state level reduce welfare by raising price dispersion. The elasticity of substitution between two differentiated goods $\varepsilon$ raises the weight of inflation fluctuations relative to the output gap because it amplifies the welfare losses associated with any given price dispersion. Nominal rigidities, whose size is inversely related to the slope of the New Keynesian Phillips curve $\kappa$, raise the degree of price dispersion resulting from any given deviation from the steady-state inflation rate.

Let $\Delta\mathbb{W}\left(\tau;\theta,\mathcal{P}\right)$ denote the welfare gains from transparency conditional on a policy of duration $\tau$.[4] To assess the desirability of transparency, we compute the *model predicted welfare gains/losses from transparency* as:

$$\Delta\mathbb{W}^e=\textstyle\sum_{\tau=0}^{\tau_a^*}\Delta W\left(\tau;\theta,\mathcal{P}\right)p^*\left(\tau\right)\tag{13}$$

where $p^*(\tau)$ stands for the ergodic probability of a passive policy of duration $\tau$. These probabilities are influenced by the central bank reputation that, in turn, depends on the probability with which the central bank engages in long-lasting deviations from the virtuous

[4] The exact formula is reported in Appendix B.

regime: $p_{12}/(1-p_{11})$. It is important to emphasize that welfare gains from transparency are not conditioned on a particular shock or policy path. Instead, the welfare gain is measured by the unconditional long-run change in welfare that arises if the central bank systematically announces the duration of any deviation from active monetary policy, given the monetary policy strategy $\phi(s_t)$, $\phi_y(s_t)$, the transition matrix $\mathcal{P}$, and the model (7)-(11).

Uncertainty about the future output gap plays only a minor role for social welfare since the posterior mean of the slope of the Phillips curve $\kappa$ is very small (see Table 1) and standard calibrations for the elasticity of substitution $\varepsilon$ range from 6 to 10. Therefore, welfare turns out to be tightly related to agents' uncertainty about future inflation, which in turn depends on the time-varying level of pessimism about observing a future switch to active monetary policy. If the central bank has lower reputation, agents take into account that long-lasting deviations from the active regime are more frequent and potentially more persistent. Consequently, agents expect more drastic inflationary or deflationary consequences from future shocks and thereby they become more uncertain about future inflation. As shown in Section 4.2, the level of pessimism responds to central bank behavior, namely the frequency and duration of deviations from active policy and the communication strategy. Section 6.1 outlines how uncertainty evolves as the central bank conducts passive policies of different duration and under different communication strategies. In Section 6.2, we use the model to assess the welfare implications of increasing central bank transparency.

## 6.1 Evolution of Uncertainty

Uncertainty is tightly linked to agents' pessimism about observing active monetary policy in the future. As shown in Section 4.2, transparency has two effects on pessimism: ($i$) pessimism rises at the beginning of the policy (henceforth, the *short-run effect of transparency on pessimism*); ($ii$) pessimism is anchored down at the end of the policy (henceforth, the *anchoring effect of transparency on pessimism*). As we shall show, these two effects play a critical role for the welfare implications of transparency.

To illustrate how uncertainty responds to pessimism, we consider the case in which the Federal Reserve conducts a forty-quarter-long deviation from active monetary policy.[5] Figure 3 illustrates the evolution of uncertainty about inflation at different horizons under transparency, first panel, and under no transparency, right panel. At each point in time, the evolution of agents' uncertainty is measured by the $h$-period ahead standard deviation of

[5] The analysis is conducted for an economy at the steady-state and hence without conditioning on a particular shock. The exercise is only conditioned on the policy path and intends to facilitate the exposition of the welfare implications of transparency in the next section.

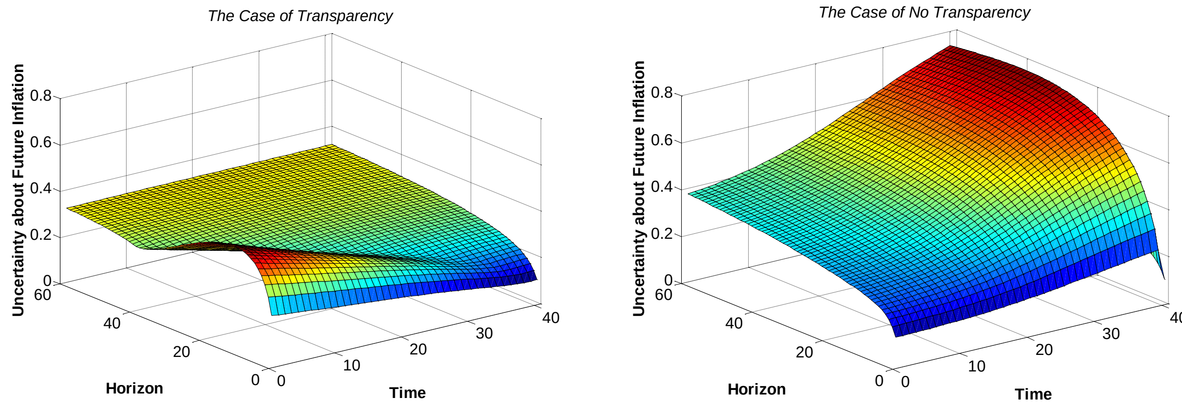


Figure 3: Evolution of uncertainty about inflation at different horizons over time. The vertical axis reports the posterior means of standard deviations in percentage points.

inflation at different horizons: $sd_i(\pi_{t+h}|\tau) = \sqrt{var_i(\pi_{t+h}|\tau)}$, $i \in \{N, T\}$.[6]

When the central bank does not announce its policy course beforehand, uncertainty about future inflation is low at the beginning of the policy because agents interpret the first deviations from active policy as short-lasting. Only after five years of passive policy agents get persuaded that the observed deviation may have a long-lasting nature and uncertainty about future inflation rapidly takes off. Note that the increase in uncertainty occurs at every horizon because agents expect passive monetary policy to prevail for many periods ahead and thereby anticipate that the inflationary/deflationary consequences of future shocks will be more severe. It is worth emphasizing that the pattern of agents' uncertainty mimics the evolution of pessimism depicted in Figure 1. Summarizing, under no transparency, following a prolonged deviation from the active regime uncertainty starts low and then gradually accelerates.

The leftward graph illustrates the dynamics of uncertainty about future inflation in the case of transparency. Upon announcement agents become suddenly more uncertain about future inflation because of the *short-run effect of transparency on pessimism*. Since agents know that the central bank will weakly adjust the policy rate to changes in the inflation rate for the next forty quarters, they anticipate more dramatic inflationary/deflationary consequences from future shocks. Compared to the case of no transparency, short-horizon uncertainty is larger at the beginning of the policy. However, at this early stage of the passive policy, uncertainty about forty-quarter-ahead inflation appears to be smaller in the case of transparency. This result is due to the *anchoring effect of transparency on pessimism*. While agents know monetary policy will be passive for forty quarters, they also know there

[6] The graphs plot the results for $h$ from 1 to 60: At horizon $h = 0$, uncertainty is zero as agents observe current inflation.

will be a switch to the active regime thereafter.[7] Announcing the timing of the return to active monetary policy determines a fall in uncertainty in correspondence of the horizons that coincide with announced date. In the graph, such a decline in uncertainty shows up as a valley in the surface representing the level of uncertainty. As we shall show, this feature of transparency has the effect of raising social welfare by systematically anchoring agents' uncertainty at the end of prolonged deviations from the active regime.

While under no transparency uncertainty *increases* across all horizons as they policy is implemented, under transparency uncertainty *decreases* across all horizons because agents are aware that the end of the prolonged period of passive monetary policy is approaching. Again, this depends on the *anchoring effect of transparency on pessimism*. Furthermore, under the active regime uncertainty about future inflation is found to be lower at every horizon under transparency. This result tends to raise the social welfare associated with transparency. Note that this finding does not hold for all parameter values and hence is due to the estimated parameters for the U.S.

Importantly, model predicted welfare gains from transparency are also affected by the ergodic uncertainty associated with the two communication strategies. Ergodic uncertainty captures agents' uncertainty about long-horizon inflation and is not affected by the current monetary policy regime. Central bank systematic behaviors, such as whether the central bank routinely announces its policy course or not, influences the ergodic uncertainty. The estimated model predicts that transparency leads to lower ergodic uncertainty than no transparency. In the next section, we will show that this fact plays a critical role for the welfare comparison between transparency and no transparency.[8]

## 6.2 Welfare Gains from Transparency

In this section, we use the model to quantify the welfare gain/loss from transparency. The solid line (right axis) in Figure 4 reports the welfare gains from transparency for different durations of passive policies. This is the graphical representation of the function $\Delta W(\tau; \theta, \mathcal{P})$ of equation (13). The vertical bars in this figure show the ergodic probabilities of the different deviations. Recall that both these objects critically affect the model's predicted gains from transparency in equation (13).[9] Figure 4 shows that welfare gains from transparency lie in

[7] That active regimes are welfare-improving is consistent with the optimal monetary policy literature in the context of simple rules (e.g., Schmitt-Grohe and Uribe, 2007, and Faia and Monacelli, 2007).

[8] For the sake of brevity, we do not discuss the evolution of uncertainty about the output gap. As mentioned before, since the estimated value of the slope of the Phillips curve $\kappa$ is very small when compared to the elasticity of substitution between goods $\varepsilon$, uncertainty about future output plays a negligible role in our welfare analysis.

[9] Note that to compute the expected welfare gains from transparency we use the ergodic distribution of policy duration, including active policy. In the graph 4, we report the ergodic distribution conditional on

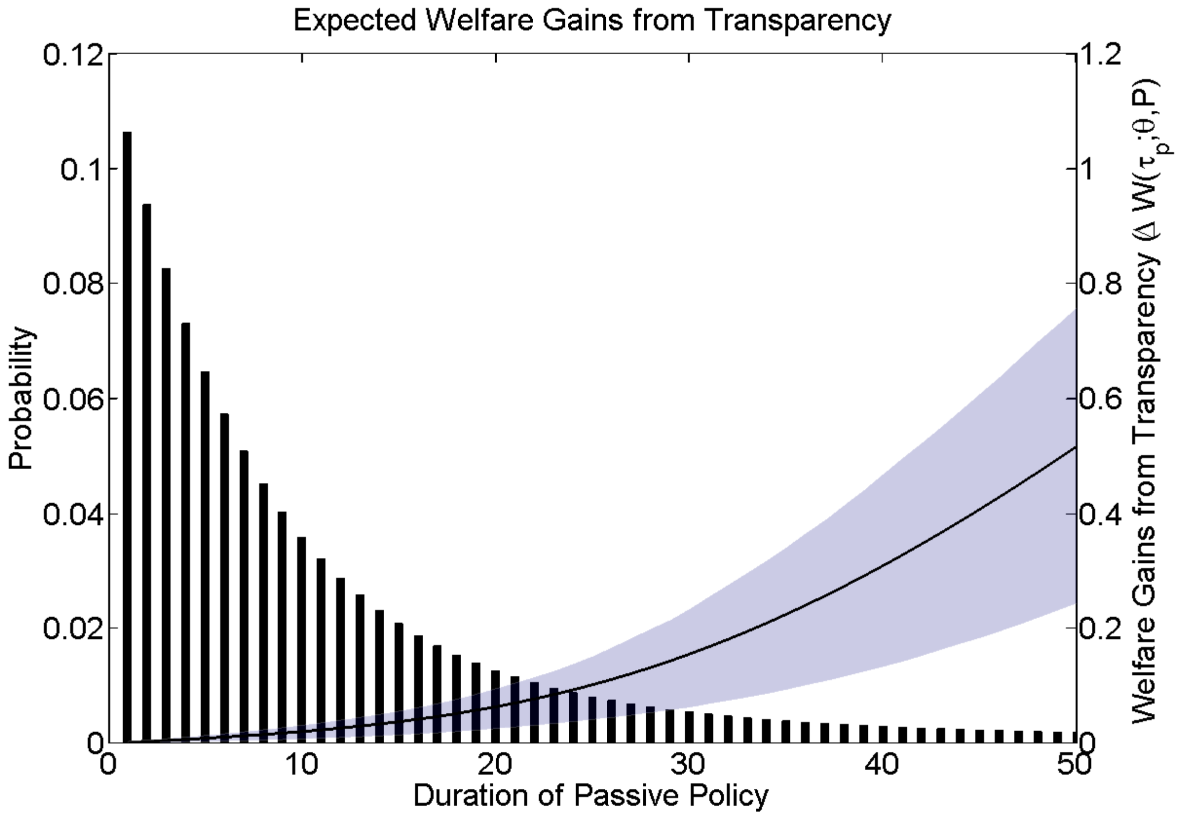


Figure 4: The solid line is the posterior mean of the welfare gains from transparency. The bars capture the posterior mean of the ergodic distribution of the duration of passive policies. The shaded area is the 60-percent posterior credible set of welfare gains from transparency.

positive territory for any considered duration of passive policy, implying that transparency would raise social welfare in the U.S.

The shape of the welfare-gain line in Figure 4 is very insightful as it is tightly linked to the *short-run effect of transparency on pessimism* and to the *anchoring effect of transparency on pessimism*. Quite remarkably, welfare gains from transparency quickly accelerate as the duration $\tau$ of passive policy rises. This feature is related to the *anchoring effect of transparency on pessimism*. These effects are clearly stronger if the duration of the deviation increases. Announcing the timing of the return to the active regime for a deviation that lasts several quarters allows the central bank to anchor agents' uncertainty at long horizons and prevent the large increase in uncertainty that arises under no transparency. On the other hand, announcing the timing of the switch for a short-lasting deviation has only modest effects because under no transparency agents' pessimism does not have enough time to take off.

Although not reported in Figure 4, the line of welfare gains starts falling for passive

passive policy. As discussed in Section 6.1, when the Federal Reserve conducts active policy the welfare gains from transparency are positive.

policies of very long duration. The reason is that announcing very long-lasting passive policies triggers a huge rise in pessimism at the beginning of the policy that offsets the welfare gains from anchoring pessimism at the end of the policy. However, the effect of policies of such a long duration on welfare is negligible given that their probability is virtually zero in the U.S.

In conclusion, even if the Federal Reserve benefits from strong reputation, transparency is found to be welfare increasing. This result stems from the fact that transparency prevents the unfolding of pessimism and increase of volatility that are associated with prolonged deviations from the active regime.

# 7 Weak Reputation

There is a quite large consensus in the literature on monetary policy that established central banks, such as the Federal Reserve and the European Central Bank, communicate less with the public than central banks that arguably do not share a similar reputation (Bernanke and Mishkin, 1997). In this section, we aim to evaluate the ability of the model to account for why central banks with weaker reputation tend to be more transparent. In the first subsection we maintain the assumption that central banks are fully credible when communicating, while in the second section we account for the possibility that weaker reputation might also affect the credibility of the announcements.

## 7.1 Perfectly credible announcements

A central bank with weaker reputation is more likely to engage in a prolonged deviation from the active regime. Therefore, we model a central bank with weaker reputation by setting the value for $p_{12}$ such that $p_{12}/(1-p_{11}) = 0.50 < 0.9689$, where 0.9689 is the value for $p_{12}/(1-p_{11})$ that has been estimated for the Federal Reserve. All other parameters are set equal to the posterior means reported in Table 1. The solid red line in Figure 5 shows the evolution of agents' pessimism associated with a forty-quarter passive policy followed by a switch to the active regime, conducted by a non-transparent central bank with weaker reputation. For comparison, the dashed black line reports the evolution of pessimism for the case of strong reputation. When announcements are perfectly credible the path for pessimism is not affected by central bank reputation and it is captured by the dotted line. This graph shows that if a central bank has weaker reputation, agents become substantially more pessimistic as soon as they observe the first realization of passive policy. This is because when observing the first deviation agents attach equal probabilities to the two passive regimes. In contrast, in the case of strong reputation, when the first deviation

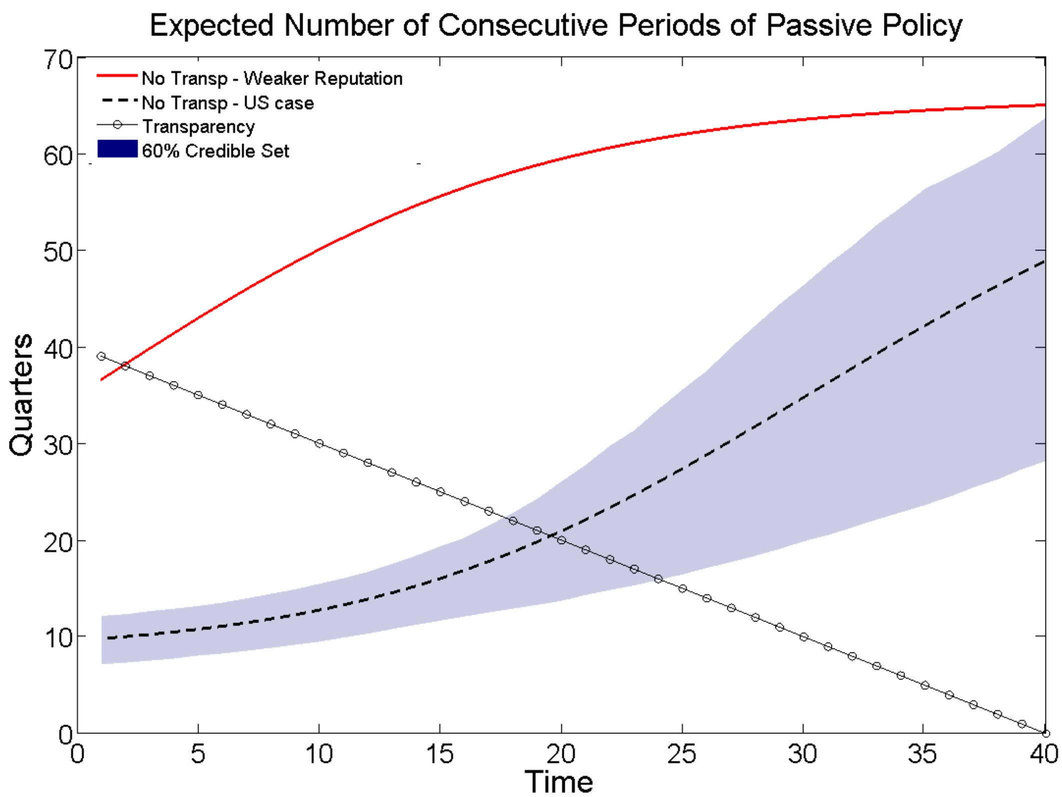


Figure 5: Evolution of Pessimism under "No Transparency" and weak reputation (the solid red line), under "No Transparency" and strong reputation (the dashed line) and under "Transparency" (the line with circles). The figure reports the posterior mean of the expected number of periods of passive policy. The shaded area denotes 60-percent posterior credible intervals. For the case of weaker reputation parameters are set to the posterior mean level.

is observed, agents think to be in the short-lasting passive regime with 96.89% probability.

Figure 6 reports the evolution of uncertainty about future inflation following the forty-quarter passive policy under different levels of reputation and transparency. Let us first compare the upper-right and the lower-right surfaces at the beginning of the policy. Compared to the Federal Reserve, central banks with weaker reputation observe uncertainty to sharply rise as the first deviation from the active regime is observed *regardless of whether they have embraced transparency or not.* This is because when reputation is weak pessimism increases sharply as soon as agents observe a deviation from the active regime, as shown in Figure 5. Thus, we should expect that embracing transparency is not going to imply large short run losses due to the *short-run effect of transparency on pessimism.* Furthermore, since the ergodic uncertainty associated with a central bank with weaker reputation is generally large, we observe a sharp reduction in uncertainty at the horizons associated with the announced return to the active regime. In the graph, this is captured by a more pronounced *valley* in the upper-right surface compared to that in the upper-left surface. Thus, we should

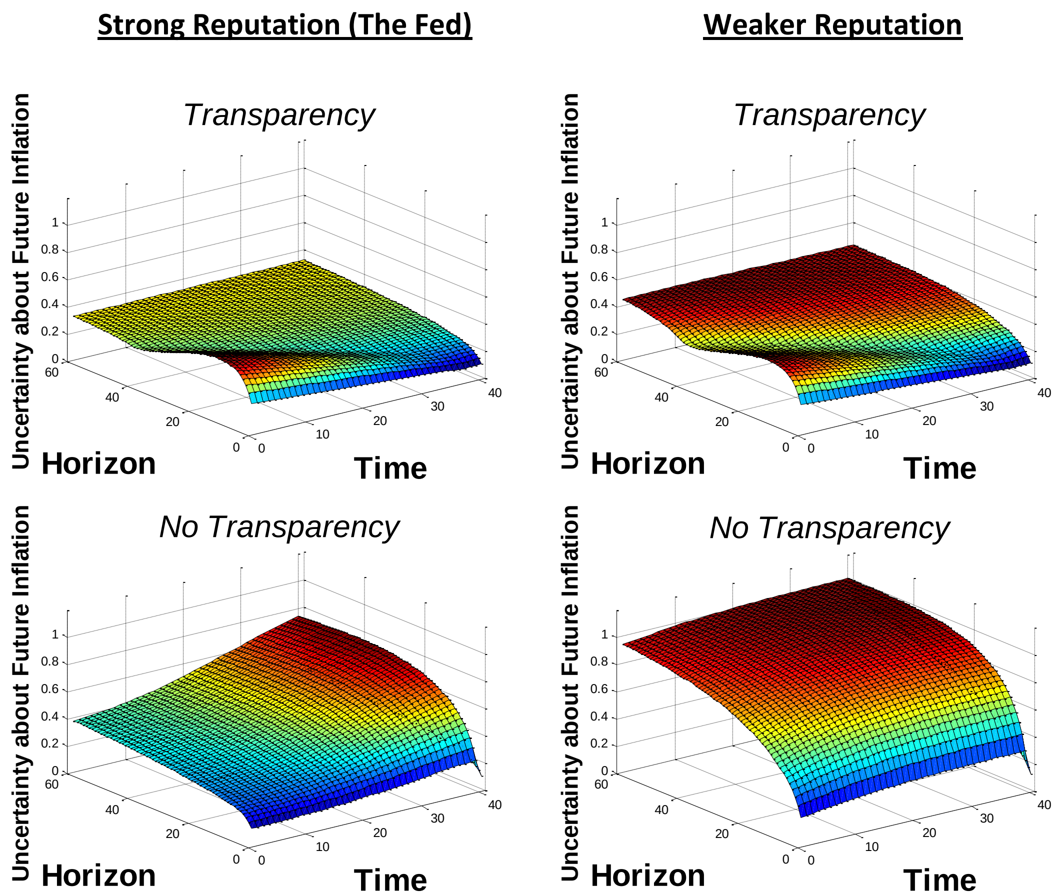


Figure 6: The evolution of uncertainty about inflation at different horizons and over time. The vertical axis reports the posterior means of standard deviations in percentage.

expect large gains from transparency deriving from the *anchoring effect of transparency on pessimism*.

Figure 7 reports the welfare gain from transparency associated with passive policies of different duration as well as the ergodic probability of conducting such policies for a central bank with a weaker reputation than the Federal Reserve. To facilitate comparison, the welfare gains and the ergodic probability of observing policy of given duration for the Federal Reserve are also reported. The solid line shows the gains from transparency for the case of weak reputation. The shaded area has been already plotted in Figure 4 and shows the range of welfare gains that the estimated model attributes to the Federal Reserve's case (i.e., the benchmark case of strong reputation). The black (white) bars refer to the ergodic probability of observing passive policy of a given duration for the central bank with weak (strong) reputation. Recall that these probability distributions are used as weights for

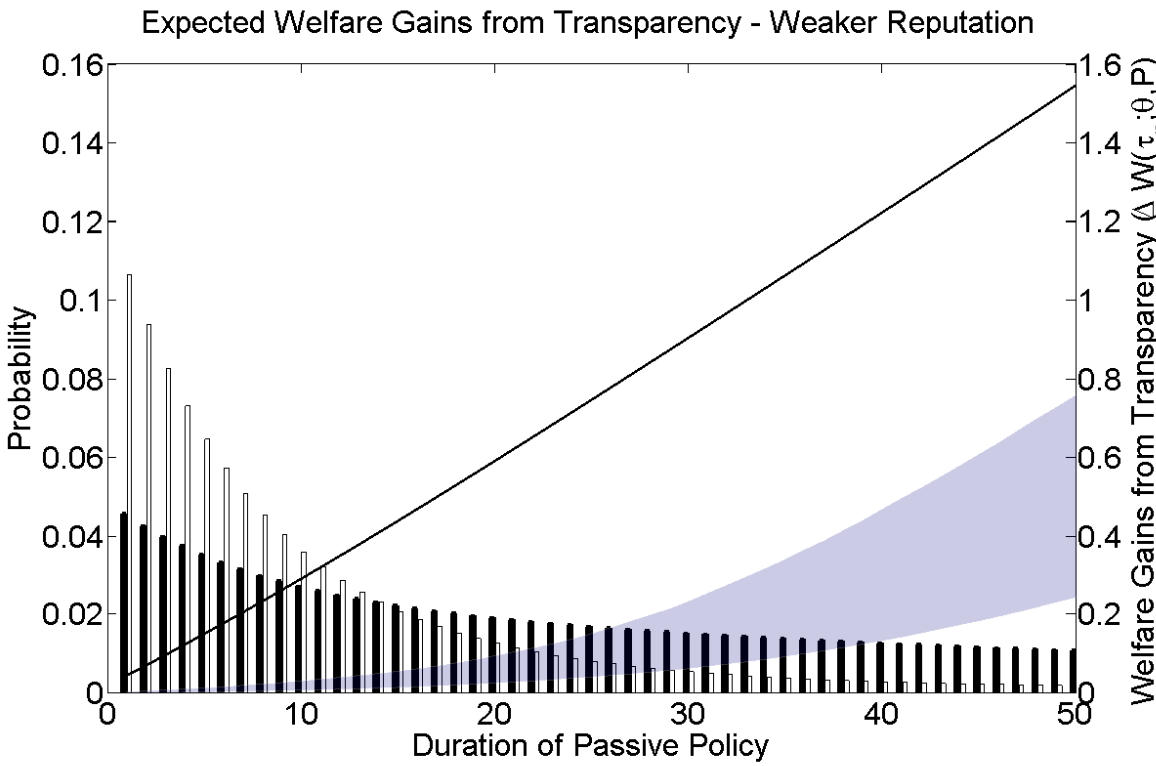


Figure 7: The solid line represents the welfare gains from transparency for a central bank with weak reputation. The shaded area is the 60-percent posterior credible set of welfare gains from transparency for the Federal Reserve (strong reputation). The black bars are the ergodic probabilities of the duration of passive policies for the central bank with weak reputation. The white bars show the posterior mean of the ergodic distribution of the duration of passive policies for the case of stronger reputation.

computing the model's predicted gains from transparency in equation (13). Since the solid line lies always above the shaded area, it follows that a central bank with weaker reputation gains more from transparency for any give duration of the passive policy. This important result is driven by the dynamic of agents' uncertainty about future inflation reported in Figure 6, which has been commented above. Furthermore, another source of gains from transparency in the case of weaker reputation stems from the higher probability of observing the long-lasting passive policies that are associated with higher welfare gains.

That gains from transparency increase as the central bank reputation becomes weaker squares well with the observation that the Federal Reserve Bank and the European Central Bank are arguably less transparent than other central banks that have been less successful at building up a strong reputation (e.g., the central banks of Brazil, Mexico, and Chile). Furthermore, the model clearly indicates that *constrained discretion* with no transparency is not a successful approach for those central banks that have failed to establish a strong reputation. In fact, in this case, even when very short-lasting passive policies are conducted pessimism strongly rises, magnifying the inflationary consequences of shocks.

## 7.2 Imperfectly Credible Announcements

We have shown before that central banks that have not succeeded in establishing a strong reputation benefit more from transparency. This result has been obtained under the assumption that those central banks are able to make credible announcements about their future deviations. However, it might well be that weaker reputation is also associated with less credibility in making announcements. To model imperfectly credible announcements, we assume that the central bank systematically announces the duration of the passive policy but it lies if the duration is longer than $\overline{\tau}$. If the drawn duration of the realized passive policy $\tau$ is smaller than or equal than $\overline{\tau}$, the central bank truthfully announces the duration $\tau_a = \tau$. If the drawn duration of the passive policy $\tau$ is larger than $\overline{\tau}$, the central bank lies, announcing a number of consecutive deviations which is uniformly distributed between 1 and $\overline{\tau}$. Agents are rational and fully understand that the central bank might lie when making an announcement $1 \leq \tau_a \leq \overline{\tau}$ and that deviations longer than $\overline{\tau}$ will never be announced. It is important to emphasize that the weaker the reputation of a central bank is, the more likely it is that a passive policy will last for more than a given number $\overline{\tau}$ of periods, and that the announcement is a lie. Therefore, for any given value of $\overline{\tau}$, the probability that a central bank lies about the duration of a deviation from the active regime falls with the strength of its reputation.

The model predicts that the credibility of announcements is key to ensure that transparency raises social welfare. To illustrate this finding we assume that a central bank with weaker reputation than the Federal Reserve (i.e., $p_{12}/(1-p_{11}) = 0.50$) announces the duration of passive policy up to $\overline{\tau} = 8$ quarters. These numbers imply that agents expect an announcement to be a lie with roughly 70% percent of probability at the moment in which the announcement is made. As shown in Figure 8, the model predicts that welfare gains from transparency are negative for any duration of the passive policy. It is interesting to note that the welfare losses do not follow a monotonic path. Instead we observe that the loss associated with an 8-period deviation is larger than the one associated with a 9-period deviation. This is because whenever a realized deviation is less than 9 periods, the central bank is in fact saying the truth, while agents think that it is potentially lying. This causes an extra welfare loss deriving from the announcement. Instead, when a deviation has a duration of at least 9 periods, there is not any additional cost, given that agents are correctly thinking that the central bank is lying.

Summarizing, enhanced transparency has to be accompanied with reforms aimed at rais-

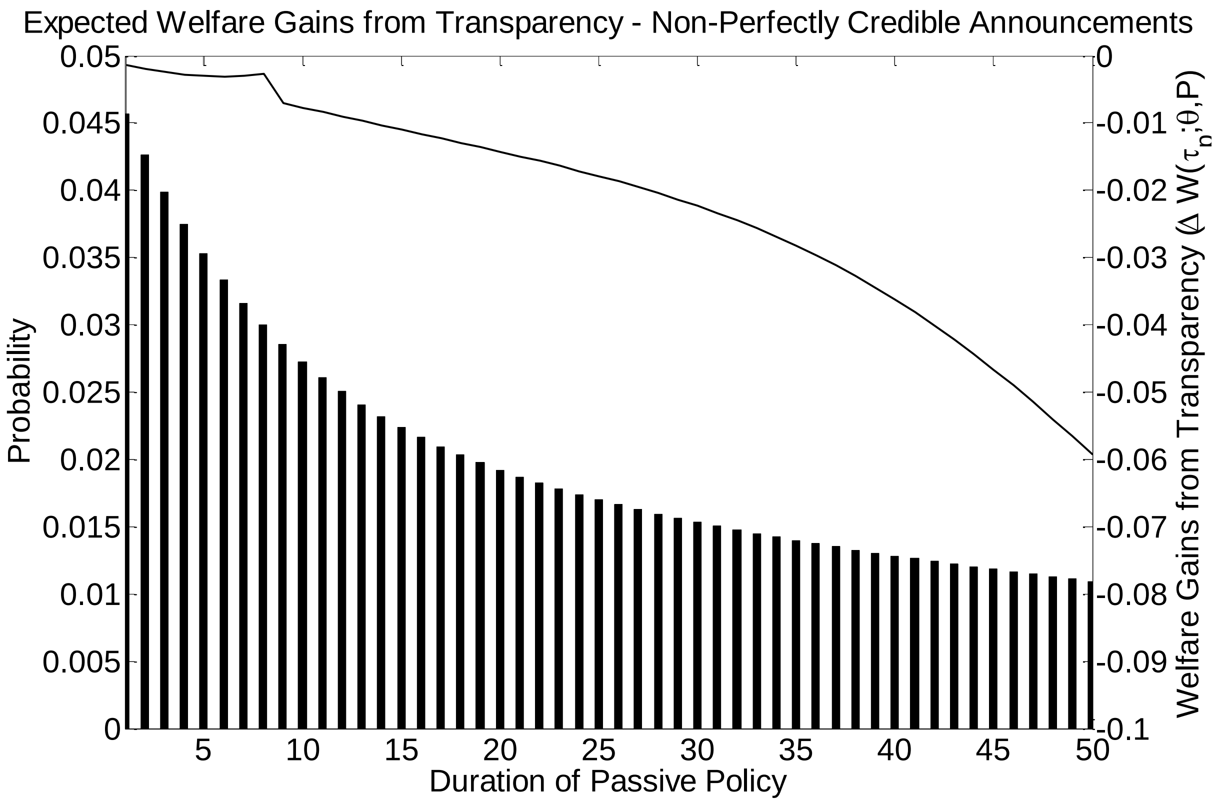


Figure 8: The blue solid line is the welfare gains from transparency for a central bank with weak reputation in the case of non-perfectly credible announcements. All other parameter values are set to the posterior means. The vertical bars are the ergodic distribution of the duration of passive policies for the central bank with weak reputation.

ing the credibility of central bank announcements. For instance, it is desirable to back up transparency with mechanisms that raise the accountability of the central bank for its announcements. These predictions square well with reality. Since the 1990s, several countries, which have been quite unsuccessful in keeping inflation low and stable, have adopted *inflation targeting*.[10] Inflation targeting can be interpreted as a form of *constrained discretion* in which transparency and accountability for central bank policy objectives are greatly emphasized (Bernanke and Mishkin, 1997). With no exceptions, all the countries that have adopted *inflation targeting* have reformed their central banks with the aim to make them more transparent and accountable for their announced policy objectives. From the perspective of our model, these reforms are crucial to justify the undeniable success of these countries in controlling inflation.[11]

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

[11] Mishkin and Schmidt-Hebbel (2007) find empirical evidence that inflation targeting helps countries to

# 8 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 a prolonged period of discretionary policy will unavoidably lead to instability of inflation expectations and inflation with associated uprising 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 that de-emphasize inflation stabilization. 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 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, uncertainty increases and welfare deteriorates.

When the model is fitted to U.S. data, we find that the Federal Reserve benefits from strong reputation. As a result, the Federal Reserve can deviate for a prolonged period of time from active monetary policy before losing control of expectations. Nevertheless, increasing the transparency of the Federal Reserve would improve welfare by anchoring agents' pessimism when facing exceptionally prolonged periods of passive monetary policy. Gains from transparency are even more sizeable for countries whose central banks have failed establishing a strong reputation. However, in this second case accountability is a key ingredient to ensure the result to the extent that it makes central bank announcements credible.

In the model, agents learn only the persistence of passive policies, while the active regime is fully revealing. This implies that agents' expectations are completely revised as soon as

have smaller inflation responses 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.

the central bank returns to the active regime. In Bianchi and Melosi (2012) we explain how to solve a model in which agents have to learn about the likely duration of both passive and active policies. This extension implies that central bank reputation varies over time. While this feature is very interesting, it is unlikely to affect the main results of the paper. This is because the anchoring effect of announcing the return to a long lasting period of active monetary policy would still have the effect of anchoring agents' pessimism and uncertainty. On the other hand, this extension would determine a substantial increase in computational time, preventing us from estimating the model. We regard estimation as an important ingredient of the paper because the proposed framework is new in the literature, with the result that the parameters controlling central bank reputation cannot be borrowed from previous contributions.

A nice feature of the paper is to introduce a convenient way to model waves of pessimism about the future 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, even if quite challenging from a computational point of view. Characterizing the optimal monetary policy in a model in which monetary policy influences the evolution of pessimism is also an important venue for future research.

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# A Modeling Transparency

This appendix provides technical details about how to solve the model in which the central bank systematically announces the duration of passive policies. We focus, first, on the case of perfectly credible announcements. We then consider the case in which central bank announcements are not fully credible. Finally, we characterize the welfare gains $\Delta\mathbb{W}(\tau;\theta,\mathcal{P})$ from announcing to agents the duration $\tau$ of the passive policy, which has been used in equation (13) to compute the model's predicted welfare gains from transparency.

## A.1 The Case of Perfectly Credible Announcements

Since the model is purely forward-looking, a sufficient statistic to solve the model with systematic policy announcements is the number of periods of announced passive policy that lie ahead before switching to the active policy. In other words, the laws of motion associated with a situation in which the central bank announces five periods of consecutive deviations from the active regime are exactly the same as that associated with a situation in which a central bank has carried out five consecutive deviations out of ten announced deviations. Therefore, we can redefine the structure of regimes as follows: Regime 1 is the active regime; Regime 2 is a regime in which only one period of announced passive policy (i.e., the current one) is left before switching to the active regime; Regime 3 is a regime in which two consecutive periods of passive policy (including the current one) will be conducted before switching to the active policy; etc. To avoid that the dimensionality of the set of regimes blows up to infinity, we truncate the duration of passive deviations to $\tau_a^*$. For any $\iota > 0$ we can find a $\tau_a^*$ such that the probability of a deviation longer than $\tau_a^*$ has probability smaller than $\iota$. Therefore, the approximation can be made arbitrarily accurate.

Endowed with this result, we can study the impact of monetary policy communication on welfare by redefine the structure of regimes in terms of number of announced deviations yet to be carried out $\tau_a$ as follows:

$$\left(\phi_\pi\left(\tau_t^a = i\right), \phi_y\left(\tau_t^a = i\right)\right) = \begin{bmatrix} \left(\phi_\pi^A, \phi_y^A\right), \text{ if } i = 1 \\ \left(\phi_\pi^P, \phi_y^P\right), \text{ if } 1 < i < \tau_a^* \end{bmatrix} \tag{14}$$

and the regimes $\tau_t^a$ governed by the $(\tau_a^*+1)\times(\tau_a^*+1)$ transition matrix $\widetilde{\mathcal{P}}^A$, which is defined as:

$$\widetilde{\mathcal{P}}^A = \begin{bmatrix} p_{11} & \widetilde{p}_A \\ \mathbf{I}_{\tau_a^*} & \mathbf{0}_{\tau_a^*\times 1} \end{bmatrix}$$

where $p_{11}$ is the probability of staying in the active regime, $\mathbf{I}_{\tau_a^*}$ is a $\tau_a^* \times \tau_a^*$ identity matrix,

$\mathbf{0}_{\tau_a^* \times 1}$ is a $(\tau_a^* \times 1)$ column vector of zeros. and $\widetilde{p}_A$ is a $1 \times \tau_a^*$ row vector whose typical $i$-th element is the probability of announcing $i$ consecutive periods of passive monetary policy followed by a switch to the active regime, conditional on being in the active regime. Formally, $\widetilde{p}_A(i) \equiv p_{12} p_{22}^i p_{21} + p_{13} p_{33}^i p_{31}$ for $1 \leq i \leq \tau_a^* - 1$ and $\widetilde{p}_A(\tau_a^*) = 1 - p_{11} - \sum_{i=1}^{\tau_a^*-1} \widetilde{p}_A(i)$. Note that the matrix $\widetilde{\mathcal{P}}^A$ is a function of the parameters of the primitive matrix $\mathcal{P}$.

## A.2 The Case of Imperfectly Credible Announcements

Let us consider the case in which the central bank systematically announces the duration of the passive policy but it lies if the duration is longer than $\overline{\tau}$. To model this, we assume that the duration of passive policies $\tau$ is drawn accordingly with the Markov-switching process implied the primitive matrix $\mathcal{P}$. If the drawn duration of the passive policy $\tau$ is smaller than or equal to $\overline{\tau}$, the central bank announces $\tau_a = \tau$. If the drawn duration of the passive policy $\tau$ is larger than $\overline{\tau}$, the central bank announces a number of consecutive deviations which is uniformly distributed between 1 and $\overline{\tau}$; that is, $\tau_a \backsim U(1, \overline{\tau})$. Agents are rational and fully understand that the central bank might lie when making an announcement. Denote the probability (conditional on being in the active regime) that the central bank lies when making an announcement with:

$$\lambda \equiv prob(\tau > \overline{\tau}) = 1 - p_{11} - \sum_{i=1}^{\overline{\tau}} \pi_i$$

where $\pi_i$ denotes the probability that the duration of the passive policy (conditional on being in the active regime) is shorter than $i$ periods; that is,

$$\pi_i \equiv p_{12} p_{22}^{i-1} p_{21} + p_{13} p_{33}^{i-1} p_{31}$$

It is important to emphasize that the probability for a central bank to lie about the duration of passive policy falls with the strength of its reputation for any given value of $\overline{\tau}$. In other words, the weaker the central bank reputation (i.e., the smaller $p_{12}/(1 - p_{11})$), the less credible the announcements.

To solve the model in which central bank's announcement are only partially credible we redefine the structure of the three regimes (i.e., active, short-lasting passive, and long-lasting passive) into a new set of regimes $\lambda_t$ determining the Taylor rule parameters as follows:

$$\left(\phi_\pi(\lambda_t = i), \phi_y(\lambda_t = i)\right) = \begin{bmatrix} \left(\phi_\pi^A, \phi_y^A\right), \text{ if } i = 1 \\ \left(\phi_\pi^P, \phi_y^P\right), \text{ if } i > 1 \end{bmatrix} \tag{15}$$

The evolution of the re-defined set of regimes $\lambda_t$ is governed by the transition matrix $\widetilde{\mathcal{P}}^A$, which for the case in which $\overline{\tau} = 4$ and $\tau^* = 7$ reads:

$$\begin{bmatrix}
P_{11} & 0 & 0 & 0 & p_1^a & 0 & p_2^a & 0 & 0 & p_3^a & 0 & 0 & 0 & p_4^a & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
1-\eta & 0 & 0 & \eta & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
1-\eta & 0 & \eta & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
1-\eta & \eta & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
1-\eta & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \eta & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
1-\widetilde{p}_{56} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \widetilde{p}_{56} & 0 & 0 \\
1-\widetilde{p}_{67} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \widetilde{p}_{67} & 0 \\
1-\widetilde{p}_{78} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \widetilde{p}_{78} \\
1-\widetilde{p}_{88} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \widetilde{p}_{88}
\end{bmatrix}$$

where we denote the probability (conditional on being in the active regime) of announcing $\tau_a = i$ consecutive periods of passive monetary policy with $p_i^a = \pi_i + \lambda/\overline{\tau}$. Furthermore, the probability that the announcement made turns out to be untrue after having observed the announced number of deviations $\tau_a$ is denoted by $\eta = \lambda/(1 - p_{11})$. Note that the matrix $\widetilde{\mathcal{P}}^A$ is a function of the parameters of the primitive matrix $\mathcal{P}$.

Note that if at $t = \tau_a + 1$ the central bank's lie is discovered, agents know that the policy will stay passive until $\overline{\tau} \geq \tau_a$. Moreover, for any periods of passive policy after $\overline{\tau}$ agents have to learn the persistence of the regime in place as in the world where no announcement is made. Note, however, that in the case of an untruthful announcement agents start learning after having already observed $\tau_a + 1$ periods of passive monetary policy.

The transition matrix for the general case (i.e., for any $\overline{\tau} \in \{1, 2, ...\}$ and $\tau^* \in \{1, 2, ...\}$

reads

$$\begin{bmatrix} \left[P_{11}, \mathbf{0}_{\overline{\tau}-1}, \left(\mathbf{0}_{1\times i-1}, p_i^a\right)_{i\in\{1,\ldots,\overline{\tau}\}}, \mathbf{0}_{1\times \max(\tau^*-\overline{\tau}+1,1)}\right] \\ \left[\mathbf{0}_{1\times\left(\overline{\tau}+\sum_{i=1}^{\overline{\tau}} i\right)}, 1, \mathbf{0}_{1\times\max(\tau^*-\overline{\tau},0)}\right] \\ \left[\mathbf{0}_{(\overline{\tau}-2)\times 1}, \mathbf{I}_{(\overline{\tau}-2)}, \mathbf{0}_{(\overline{\tau}-2)\times\left(\sum_{i=1}^{\overline{\tau}} i\right)+\max(\tau^*-\overline{\tau},0)+2}\right] \\ \left[\begin{bmatrix} 1-\eta, \mathbf{0}_{1\times(\overline{\tau}-i-1)}, \eta, \mathbf{0}_{1\times i-1} \\ \mathbf{0}_{i-1\times\overline{\tau}} \end{bmatrix}, \begin{bmatrix} \mathbf{0}_{1\times\left(\sum_{j=1}^{\overline{\tau}} j\right)+\max(\tau^*-\overline{\tau}+1,1)} \\ \mathbf{0}_{i-1\times\sum_{j=1}^{i-1} j}, \mathbf{I}_{i-1\times i-1}, \mathbf{0}_{i-1\times\left(\sum_{j=i+1}^{\overline{\tau}} j\right)+\max(\tau^*-\overline{\tau}+1,1)+1} \end{bmatrix}\right]_{i\in\{1,\ldots,\overline{\tau}-1\}} \\ \begin{bmatrix} 1-\eta, \mathbf{0}_{1\times(\overline{\tau}-1)+\left(\sum_{i=1}^{\overline{\tau}} i\right)}, \eta, \mathbf{0}_{1\times\max(\tau^*-\overline{\tau},0)} \\ \mathbf{0}_{\overline{\tau}-1\times\overline{\tau}+\left(\sum_{i=1}^{\overline{\tau}-1} i\right)}, \mathbf{I}_{\overline{\tau}-1}, \mathbf{0}_{\overline{\tau}-1\times 1+\max(\tau^*-\overline{\tau}+1,1)} \end{bmatrix} \\ \left[\widetilde{P}_{\overline{\tau}+1:\tau^*+1,1}, \mathbf{0}_{\max(\tau^*-\overline{\tau}+1,1)\times\overline{\tau}-1+\sum_{i=1}^{\overline{\tau}} i}, \widetilde{P}_{\overline{\tau}+1:\tau^*+1,\overline{\tau}+1:\tau^*+1}\right] \end{bmatrix}$$

# B Welfare Gains from Transparency

Suppose that the central bank, which is currently conducting an active policy, decides to deviate for the next $\tau$ consecutive periods. The welfare gains from transparency (i.e., from announcing to agents the duration $\tau$ of the passive policy) can be computed as follows:

$$\begin{aligned} \Delta\mathbb{W}(\tau;\theta,\mathcal{P}) &= \sum_{i=1}^{\tau} \mathbb{W}_T\left(\min\left(\tau-i,\tau_a^*-1\right)+2;\theta,\mathcal{P}\right) - \mathbb{W}_N\left(\min\left(i,\tau_*\right)+1;\theta,\mathcal{P}\right) \\ &\quad + \left[\mathbb{W}_T\left(1;\theta,\mathcal{P}\right) - \mathbb{W}_N\left(1;\theta,\mathcal{P}\right)\right] \end{aligned}$$

where the welfare functions $\mathbb{W}_i(\tau;\theta,\mathcal{P})$, $i\in\{N,T\}$, are defined in equation (12) and the last term within square brackets is the welfare gain from systematically announcing the length of deviations when the monetary policy will switch to the active regime after the $\tau$ deviations are carried out.