

Inflation Dynamics During and After the Zero Lower Bound

presented by

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Introduction

In this presentation I will examine inflation dynamics during and after periods in which nominal interest rates are close to zero and monetary policy is constrained by the zero-lower-bound (ZLB). The presentation has three parts.

First, we will take a look at inflation rates and inflation expectations from the three largest economies in which interest rates reached the ZLB in recent years: Japan, the U.S., and the Euro Area. Second, I will turn to a dynamic stochastic general equilibrium (DSGE) model for monetary policy analysis to understand the differences between inflation dynamics in the three economies. Third, I will provide a discussion of several policy implications of the model.

I Data

Figure 1 of the handout depicts inflation rates and inflation expectations for the three economies. The panels on the left show the monetary policy rates as well as GDP deflator inflation and CPI inflation. The grey shaded areas indicate the ZLB episodes. Two observations from Figure 1 stand out.

First, while inflation rates in Japan have been mostly negative, the ZLB episode in the U.S. is associated with positive inflation, implying negative real rates. In the Euro Area inflation rates have been falling toward the end of the sample as the policy rate has approached zero. Second, long-run inflation expectations have been remarkably stable in the U.S. and the Euro Area, despite falling policy rates. In Japan, on the other hand, long-run inflation expectations have been more volatile and, even more remarkable, they stayed around 1% although the average inflation rate over the past 15 years was negative.

II DSGE Model

In Part 2 of the presentation we look at inflation dynamics through the lens of a New Keynesian DSGE model. Although DSGE models abstract from the complexities of modern-day economies, they provide a useful framework to analyze the dynamics of output, inflation, and interest rates as well as the potential effects of monetary and fiscal policy interventions.

I would like to highlight three features of the DSGE model used in our paper. First, inflation is determined by the New Keynesian Phillips curve. The New Keynesian Phillips curve has been recently criticized by prominent macroeconomists because the absence of deflation in the U.S. in the aftermath of the Great Recession seems to be inconsistent with the drop in real activity. However, joint research with Marco Del Negro and Marc Giannoni from the New York Fed and work by Coibon and Gorodnichenko has shown that the missing deflation puzzle disappears once one accounts for the forward-looking nature of and the role of expectations in the Phillips curve relationship.

Second, monetary policy is represented by an interest rate feedback rule. The central bank adjusts interest rates in response to inflation and output gaps. The ZLB enters the model as a constraint on the monetary policy rate which is restricted to be non-negative. Third, macroeconomic fluctuations are generated by so-called shocks, which are unanticipated changes in economic fundamentals such as productivity, aggregate demand, and government policies.

Multiple Equilibria. DSGE models are well-suited to assess the effect of changes in monetary and fiscal policies. However, we first need to overcome an important challenge. The predictions coming out of typical DSGE models with ZLB constraints are ambiguous, which is illustrated in Figure 2. The figure depicts the Fisher equation which states that the nominal interest rate equals the real rate plus inflation (red line) and the monetary policy rule (blue line). Here we abstract from the presence of shocks and focus on the so-called steady states.

The model predicts that two outcomes are possible: (A) inflation is equal to the value targeted by the central bank and nominal interest rates are positive. (B) Inflation rates are negative and nominal interest rates are zero. We refer to (A) as the targeted-inflation outcome and (B) as the deflation outcome.

Technically speaking, the model has multiple equilibria: given the same set of economic fundamentals, which is the real rate in our illustrative example, different economic outcomes are possible. Multiplicity is both a blessing and a curse. It is a blessing for empirical researchers who are trying to explain very different macroeconomic experiences, say, zero interest rates and positive inflation in the U.S. and zero interest rates and deflation in Japan, with a single economic model. It is a curse for policy makers, because the same policy action of, say, changing interest rates or raising government spending, may have very different effects, depending on the equilibrium.

However, there is also an opportunity for policy making: actions and statements of central banks may influence the coordination of beliefs among private sector agents and lead to the selection of a desirable equilibrium. Moreover, one can attempt to design policies that make some outcomes, preferably the undesirable ones, unsustainable. I will come

back to this point at the end of my presentation.

I previously gave you an example of multiplicity. Unfortunately, this example was too simple for an empirical analysis, because it abstracted from the shocks that constantly hit the economy. An economy could experience low interest and inflation rates because of adverse fundamental shocks or because of a switch from a targeted-inflation regime to a deflation regime.

In the paper we constructed an equilibrium for a prototypical DSGE model that is able to disentangle the two scenarios: it features shocks to fundamentals as well as a belief shock that serves as a coordination device for agents' expectations and can move the economy from a targeted-inflation regime to a deflation regime and vice versa.

Empirical Analysis. We fit our model to pre-ZLB data from the three economies, under the assumption that prior to the ZLB episodes all countries were in the targeted-inflation regime. To assess whether we have observed a shift to the deflation regime, we conduct the following analysis in Figure 3 of the handout:

We characterize the joint distribution of inflation and interest rates conditional on the two regimes. The contours in the figure can be interpreted as coverage sets: for instance, the probability that inflation and interest rates fall into the region delimited by the contour labeled 0.95 is 95%. The panels on the left correspond to the targeted-inflation regime, which means that with high probability inflation is close to the central bank's target. Under this regime, reaching the ZLB is a rare event because it requires an unlikely sequence of fundamental shocks. The panels on the right show the outcomes under the deflation regime, where inflation is typically negative and interest rates are close to zero. However, there is also overlap in the regime-conditional distributions: under both regimes it is possible to observe low interest and inflation rates.

The black stars represent non-ZLB observations which have been used to estimate the model parameters. Not surprisingly, they mostly fall within the contours associated with the targeted-inflation regime. More interesting are the green stars, which correspond to near-zero interest rate periods. For Japan these observations appear to be more likely conditional on the deflation regime than under the targeted-inflation regime. For the U.S. the

comparison is more ambiguous, whereas for the Euro Area a shift to the deflation regime at the current stage looks unlikely to have occurred.

The examination of the contour plots ignores the model's predictions for other observables and the information from dynamic correlations. It is no substitute for the formal econometric analysis conducted in our companion paper, where we concluded from a slightly different model that the U.S. did not enter a deflation regime in 2009, whereas Japan did, starting in 1999.

III Policy Questions

In Part 3 of this presentation, I will focus on several policy-related questions, starting with:

How Bad is Deflation? If deflation is caused by an adverse demand shock, it is the direct effect of the adverse shock rather than deflation that causes most of the harm to the economy. However, there are also some direct costs associated with very low (but also very high) inflation rates. New Keynesian models make the assumption that it is costly for firms to adjust prices at a rate which differs from some baseline inflation rate. This cost leads to an inefficiency because the economy will be operating inside the production possibility frontier. While the output loss is not directly observable in the data, in the model it is linked to the slope of the New Keynesian Phillips curve, which can be estimated. The New Keynesian distortion makes deflation as well as very high inflation rates undesirable.

It is important to keep in mind, though: if firms were to adjust their price-setting technologies, for example, through automatic indexation to trend inflation, then most of the costs associated with inflation rates outside of the interval of 0 to 2% could be eliminated. On balance, most estimated DSGE models currently used in monetary policy analysis at best point to a modest cost of deflation.

We now turn to two experiments in which we examine the consequence of changing the target inflation rate. In our estimated model the target inflation rate corresponds to the average between 1984 and 2007 which is 50 basis points higher than the golden rule of 2%.

Experiment 1. In our first experiment we ask the following question: what would have happened in the U.S., had the Fed targeted a 4% inflation rate throughout our sample? The results are depicted in Figure 4 of the handout. The solid black lines correspond to the actual data. We consider two alternative scenarios, depicted in blue and red. If you cannot see the red line, it means that it is hiding behind the blue line.

Under the red scenario, we simply change the target inflation rate to 4% and assume that the economy is experiencing the same fundamental shocks that actually occurred. First, prior to 2009 interest and inflation rates are shifted upward by 1.5%, which is the difference between the two inflation targets. Second, to focus on the benefit associated with the 4% target, we assume in this experiment that firms adjust their price-setting technology to the new target rate, which implies that the path of output under the two scenarios is virtually identical until the end of 2008. Third, after 2008 the ZLB never binds in the red scenario. Inflation never drops below zero and promptly returns near the target. Fourth, the recovery in GDP is somewhat faster under the red scenario than in the data.

A non-binding ZLB between 2009 and 2014 would have given the Fed the ability to conduct conventional expansionary monetary policy by lowering interest rates to zero. We consider such a policy in our second scenario. Using a sequence of unanticipated monetary policy shocks, we reduce the nominal interest rate to zero under the 4% target.

The path of variables under this scenario is shown in blue. Here the return of inflation to average levels is even quicker and recovery of GDP takes about a year less than it actually did. The last panel shows that after 2009 consumption is substantially higher relative to the benchmark under both scenarios.

Unfortunately, raising the inflation target is also associated with a cost that is not shown in Figure 4: if the public does not adjust their price and wage-setting technology to the higher level of inflation and the 4% average inflation rate leads to increased price adjustment costs, then there would be an output and welfare loss associated with the New Keynesian channel. Moreover, there could be costs, not captured in our model, for example, related to the cost of holding cash balances.

From an *ex ante* perspective, the costs and benefits of the policy have to be weighted by the probability of reaching the zero lower bound. As we mentioned before, conditional on being in the targeted-inflation regime, this probability is very small, even under a 2 - 2.5% target rate. Thus, the costs are potentially incurred over a long period of time without reaping any benefits.

Moreover, as Japan's experience illustrates, spending a considerable amount of time at the ZLB may be unrelated to the central bank's inflation target. Thus, from an *ex ante* perspective, the case for a higher inflation target is not particularly strong.

Experiment 2. As a second experiment, consider a hypothetical switch to a 4% target rate in 2014:Q1, conditioning on the state of the U.S. economy at the end of 2013:Q4 and conditioning on the U.S. being in the targeted-inflation regime. Results are depicted in Figure 5 of the handout. Here we simulate future fundamental shocks. Each hair corresponds to a different stochastic simulation.

First, notice that even under the benchmark target (black lines), the model predicts a lift-off from the ZLB. This prediction is common to many DSGE models, indicating that the current monetary policy is, by historical standards, unusually expansionary. Second, the interest rate, output, and inflation forecasts reflect substantial uncertainty. Under the benchmark scenario there remains a risk of deflation as late as 2017. Third, the lift-off from the ZLB is faster under the four percent target inflation rate (red lines) and the deflation risk is reduced. Fourth, while the change in the target inflation rate affects interest rate and inflation dynamics, the path of GDP is largely unaffected.

Thus, this analysis suggests that if the Fed raises the inflation target now, even if it is able to communicate and convince the public about the credibility of this new policy, the expected real effects of this policy change are essentially zero. As we saw from Experiment 1 the only positive effect would be the ability to execute unanticipated expansionary monetary policy actions on trajectories along which adverse shocks push the economy back toward the ZLB. In the case of Japan, which according to our analysis has a high likelihood of being in the deflation regime, raising the target inflation rate would also have no significant effect, because raising the target rate, does not eliminate the deflation regime.

Finally, one should also seriously consider the potentially adverse effect of the target rate change on the credibility of the central bank.

Let me now consider some policy issues that transcend our quantitative model.

Managing Expectations. Our model features a belief shock that determines the inflation regime. It serves as a coordination device for agents in the model. In reality it is conceivable that a central bank has considerable influence on this expectation coordination through its communication. In fact, in our companion paper we argue that the aggressive unconventional monetary policies in the U.S., in contrast to the more measured and possibly contradictory responses of the Bank of Japan, may have prevented a switch to the deflation regime in the U.S.

Eliminating the Deflation Steady State / Regime. Throughout this presentation I have stressed multiplicity of equilibria in workhorse New Keynesian DSGE models. In closing, I provide a brief discussion of some policy proposals that interact with these multiplicities.

Let's return to Figure 2 of the handout. Abstracting from fundamental shocks and focusing on steady states, the deflation outcome could be eliminated by (a) a policy rule that raises the nominal interest rate above the real rate once inflation becomes negative; or (b) by responding less strongly to the inflation gap such that the policy rule is flatter than the Fisher equation in the graph. Policy (b) is called passive monetary policy.

Switching to the discontinuous monetary policy rule (a) does not seem to be a solution for the U.S. because, according to our analysis, the U.S. economy is still in the targeted-inflation regime and, moreover, inflation is not low enough to have reached what would be a reasonable threshold for a jump in the interest rate. For Japan, the quantitative assessment of such a policy would be interesting and is indeed a topic of our ongoing research.

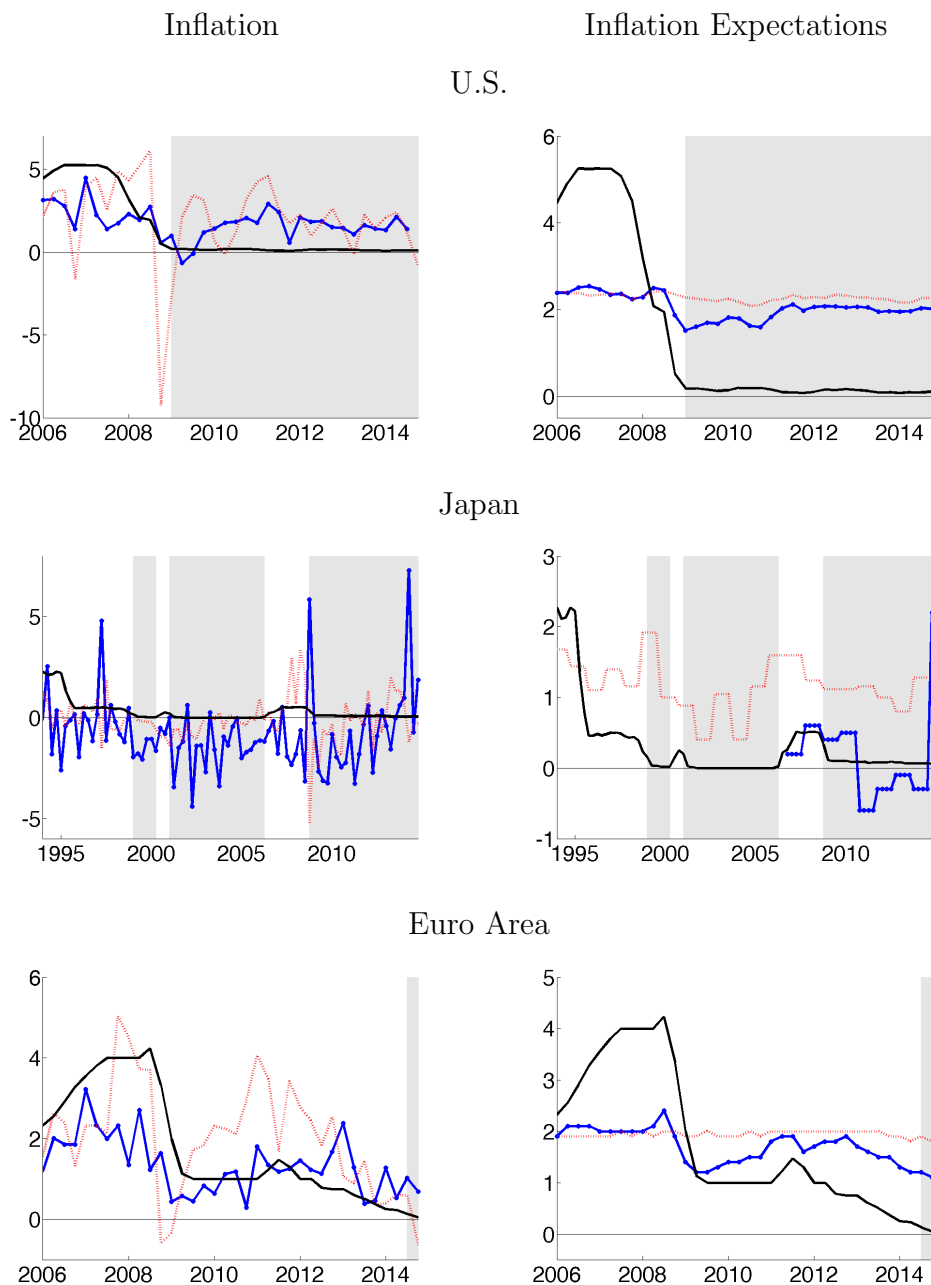
The downside of the passive monetary policy (b) is that in combination with a passive fiscal policy, that is a fiscal policy that only responds weakly to the level of real government debt, it opens the door for *undesirable* belief-shock induced fluctuations of output, inflation and interest rates around the targeted-inflation steady state.

A solution could be provided by either combining the passive monetary policy with a fiscal policy that is active in the sense that it responds strongly to the level of government debt. Or, by using a fiscal policy that responds to the nominal level of debt or directly to the level of inflation, signaling to the public that the deflation steady state is fiscally unsustainable.

Let me conclude by reiterating that

- the ZLB creates multiplicity of equilibria that can lead to very different inflation outcomes;
- central bankers need to pay attention;
- it is important to conduct monetary policy in a way that (a) prevents the coordination of private sector expectations on a deflationary level; and (b) eliminates the possibility of a deflation regime altogether.

Figure 1: INFLATION AND INFLATION EXPECTATIONS



Notes: Left panels: monetary policy interest rate (solid black), CPI inflation (dotted red), GDP deflator inflation (solid-dotted blue), where the latter two are annualized quarterly rates. Right panels: monetary policy interest rate (solid black), 5-year-ahead (10-year-ahead for Japan) inflation expectations (dotted red), 1-year-ahead inflation expectations (solid-dotted blue). The shaded gray intervals characterize the ZLB episodes.

Figure 2: Targeted Inflation (A) and Deflation (B) Steady States

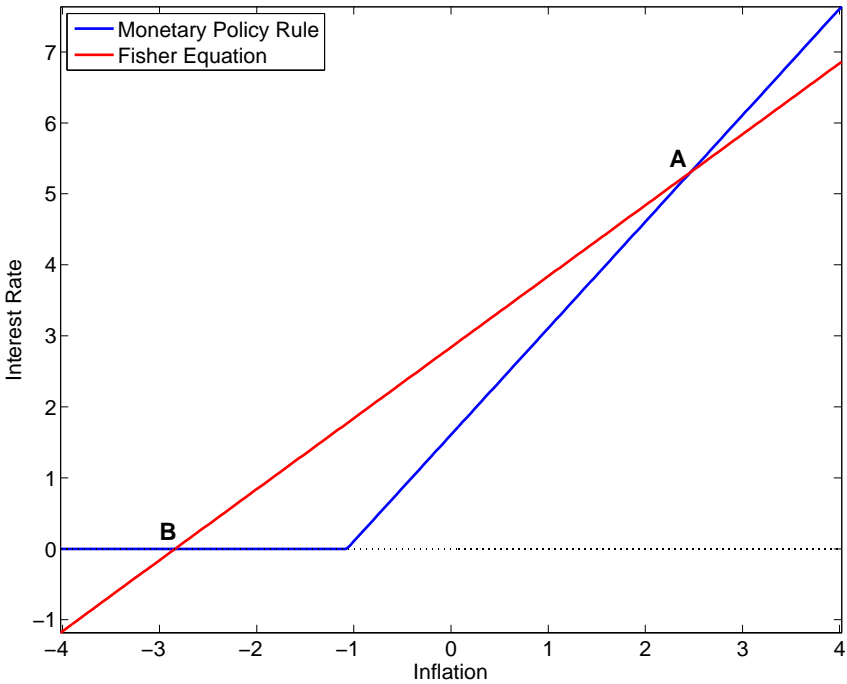
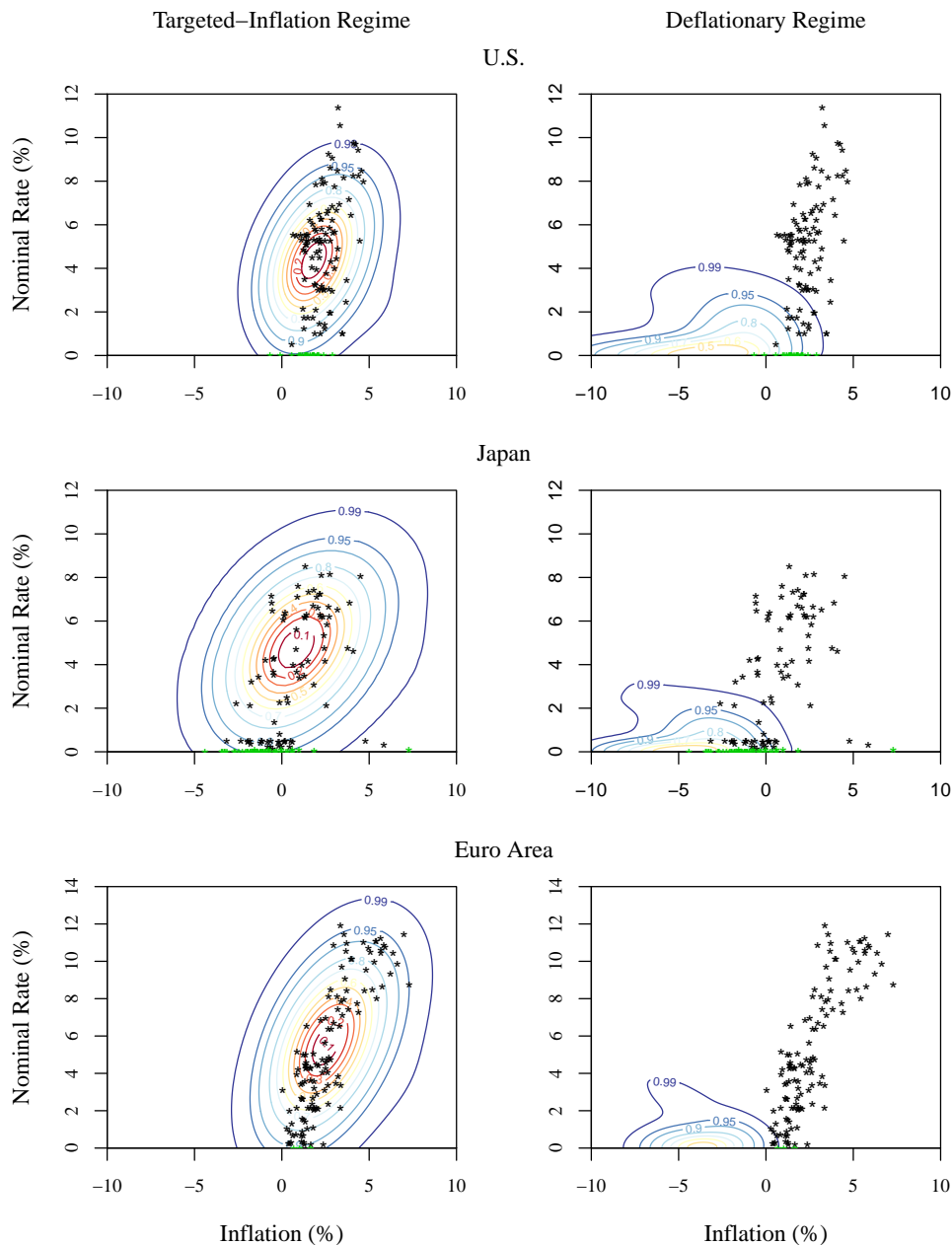
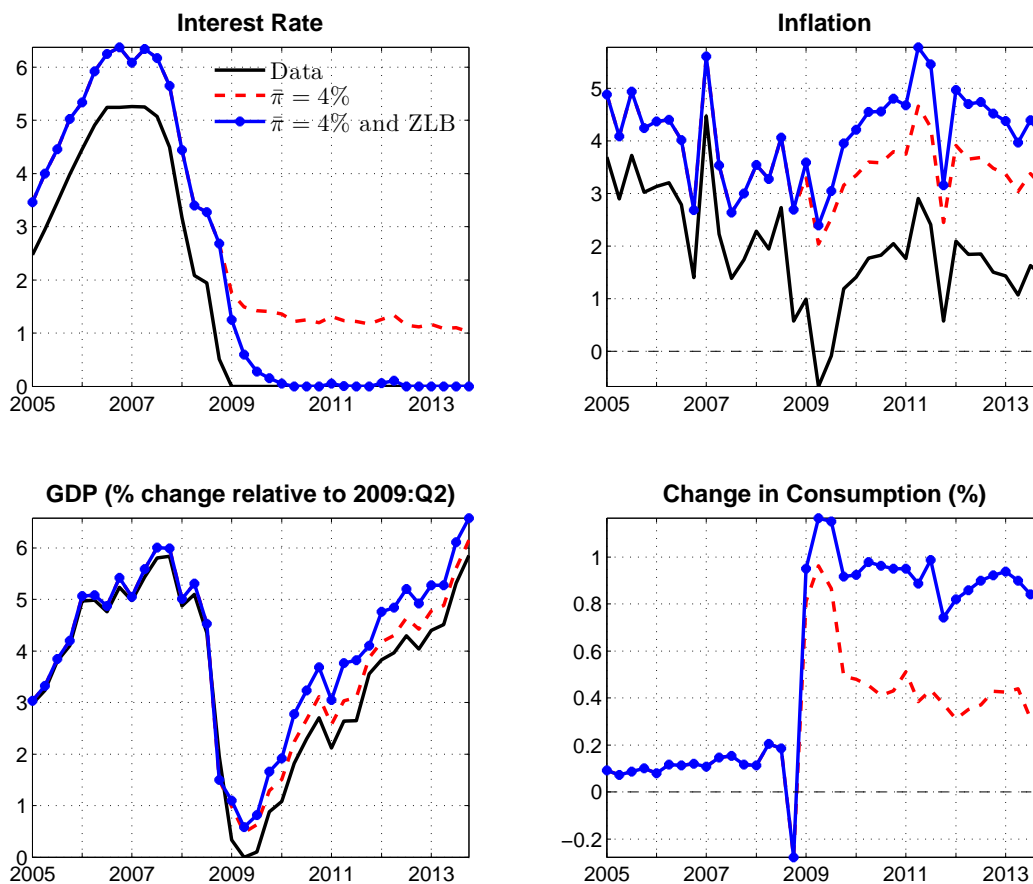


Figure 3: Ergodic Distribution and Data



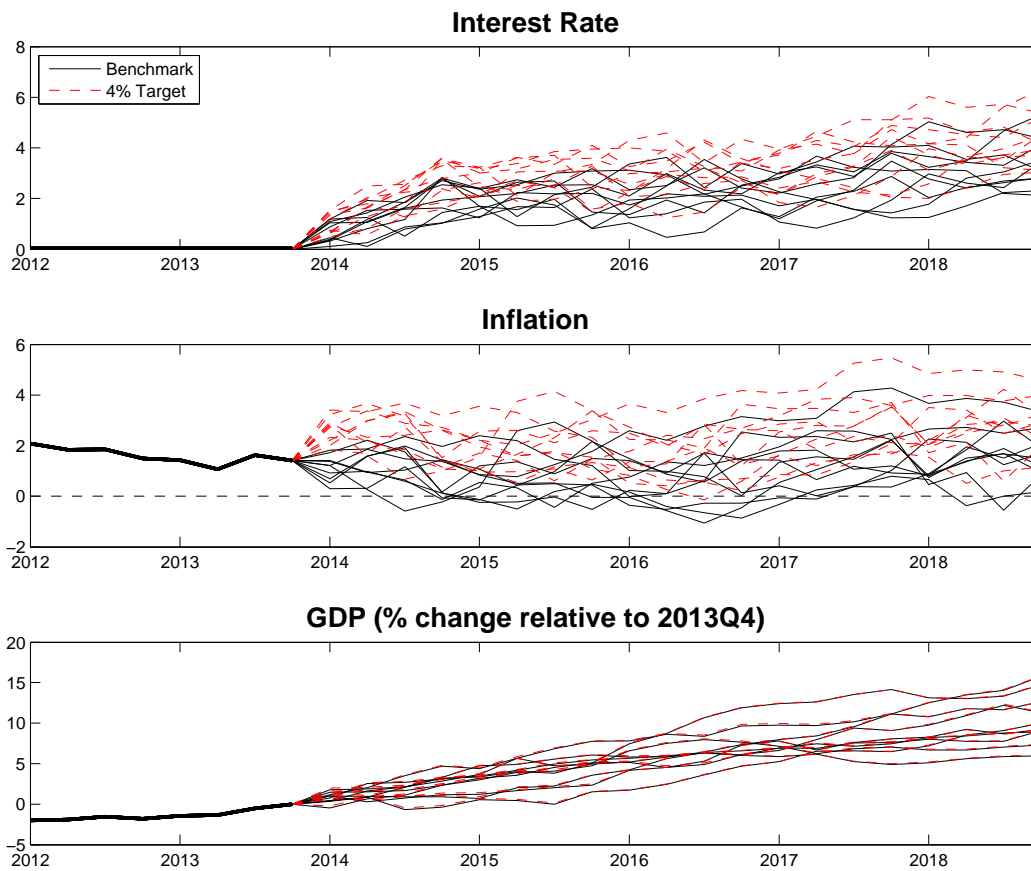
Notes: In each panel we report the joint probability density function (kernel density estimate) of annualized net interest rate and inflation, represented by the contours. Black stars represent non-ZLB observations: 1984:Q1 - 2008:Q4 (U.S.), 1981:Q1 - 1998:Q4, 2000:Q2-2001:Q1, 2006:Q3-2008:Q4 (Japan), 1984:Q1 - 2014:Q2 (Euro Area). Green stars represent the remaining observations, all which feature the ZLB.

Figure 4: EXPERIMENT 1: LONG-RUN INFLATION TARGET OF 4% SINCE 1984



Notes: Solid black lines correspond to the benchmark policy and reproduce the actual data. Dashed red lines correspond to a counterfactual policy with a target inflation rate of 4% ($\bar{\pi} = 1.01$). Solid-dotted blue lines correspond to a counterfactual target of 4% and a sequence of expansionary monetary policy shocks $\epsilon_{R,t}$ that lower the interest rate to zero. The percentage change in consumption depicted in the bottom right panel is relative to the benchmark policy.

Figure 5: EXPERIMENT 2: INFLATION TARGET OF 4% STARTING 2014



Notes: The black lines prior to 2014:Q4 represent actual U.S. data. The subsequent (black) hairs correspond to simulated trajectories under the prevailing policy. The red dashed lines correspond to simulated trajectories (based on the same sequence of stochastic disturbances) under the counterfactual 4% target.