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Escaping the Great Recession

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Abstract

While high uncertainty is an inherent implication of the economy entering the zero lower bound, deflation is not, because agents are likely to be uncertain about the way policymakers will deal with the large stock of debt arising from a severe recession. We draw this conclusion based on a new-Keynesian model in which the monetary/fiscal policy mix can change over time and zero-lower-bound episodes are recurrent. Given that policymakers' behavior is constrained at the zero lower bound, beliefs about the exit strategy play a key role. Announcing a period of austerity is detrimental in the short run, but it preserves macroeconomic stability in the long run. A large recession can be avoided by abandoning fiscal discipline, but this results in a sharp increase in macroeconomic instability once the economy is out of the recession. Contradictory announcements by the fiscal and monetary authorities can lead to high inflation and large output losses. The policy trade-off can be resolved by committing to inflate away only the portion of debt resulting from an unusually large recession.

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1 Introduction

The recent financial crisis and the recession that followed led to an increase in macroeconomic uncertainty (Jurado, Ludvigson, and Ng 2013) and to a substantial change in the conduct of monetary policy, with interest rates stuck at the zero lower bound for the past four years. While in a new-Keynesian framework the zero lower bound is associated with deflation, inflation in the data has remained remarkably close to its target value. Following Hall's Presidential Address to the American Economic Association, some researchers have labeled this observation the "Bob Hall's puzzle" (Hall 2011). At the same time, the crisis has triggered a widespread policy debate about the best way to mitigate the consequences of a deep recession once monetary policy is constrained by the zero lower bound. While this debate is animated by a wide spectrum of opinions, there seem to be two popular polar views. The first one advocates a discontinuity with respect to the policies of the past, calling for a robust fiscal intervention, perhaps associated with a reduction on the focus on inflation stabilization. The second one strongly opposes the idea of explicitly abandoning policies that have arguably led to a stable macroeconomic environment since the Volcker disinflation. As a result of this debate, policy uncertainty is at historical maxima (Baker, Bloom, and Davis 2011). In this paper, we will show that *policy* uncertainty can account for both the absence of deflation and the increase in *macroeconomic* uncertainty.

We construct a dynamic general equilibrium model that captures the policy trade-off that seems to characterize the current economic environment: choosing between mitigating a large recession and preserving a reputation for fiscal discipline. In the model, when the zero lower bound is not binding, policymakers' behavior is characterized by two very distinct policy combinations. Under the *Monetary led policy mix,* the fiscal authority moves primary surpluses in response to fluctuations in the ratio of public debt to gross domestic product (GDP), while the central bank reacts strongly to deviations of inflation from its target. If agents expect this regime to prevail for a long time, any fiscal imbalance is backed by future fiscal adjustments and reputation for fiscal discipline is strong. Under the *Fiscally led policy mix,* the fiscal authority does not react strongly enough to debt fluctuations and the central bank disregards the Taylor principle. In this second case, agents understand that policymakers are unlikely to implement the fiscal adjustments necessary to preserve debt stability.[1] Periodically, a large swing in preferences induces agents to substantially reduce consumption. In this case, a standard Taylor rule would imply a negative nominal interest rate. This forces policymakers into a *zero lower bound regime* in which the federal funds rate is restricted to zero and the fiscal authority disregards the level of debt in an attempt to mitigate the resulting deep recession. As in Krugman (1998), Eggertsson and Woodford (2003), and Christiano, Eichenbaum, and Rebelo (2011), the real

[1] In the language of Leeper (1991) the Monetary led regime corresponds to Active Monetary policy and Passive Fiscal policy, whereas the Fiscally led regime is associated with Passive Monetary policy and Active Fiscal policy.

interest rate is now too high with respect to what would be desirable. Policymakers would then find it beneficial to induce a jump in inflation expectations in order to cause a drop in real interest rates and push the economy out of the recession.

We first point out that when the possibility of entering the zero lower bound is ruled out, the Monetary led regime is preferable to the Fiscally led regime because the former leads to a more stable macroeconomic environment. When policymakers are expected to follow the Monetary led rule for many periods ahead, all the shocks that hit the debt-to-GDP ratio are neutralized by the fiscal authority and the economy is therefore insulated with respect to fiscal disturbances. However, if the Fiscally led regime is expected to be in place most of the time, agents realize that inflation, not taxation, will be used to keep debt on a stable path. Therefore, all the fiscal imbalances that are systematically neutralized under the Monetary led regime will now affect inflation. In the presence of nominal rigidities, inflation volatility translates into output volatility, resulting in a more uncertain macroeconomic environment.

We then show that while high uncertainty is an inherent implication of the economy entering the zero lower bound, deflation is not. This is because agents are likely to be uncertain about the way policymakers will deal with the large stock of debt arising from a severe recession. Given that at the zero lower bound policymakers' behavior is in fact constrained, agents' beliefs about policymakers' behavior once the economy is *out* of the zero lower bound play a key role in determining macroeconomic outcomes *at* the zero lower bound. We model this idea by introducing a series of regimes that are characterized by the same policy rules but that differ in terms of the exit strategy.

If policymakers announce that as the economy exits the zero lower bound, a prolonged period of fiscal discipline will follow, inflation expectations drop, leading to deflation and a severe recession. Therefore, while the Monetary led policy mix is desirable during regular times, it can be detrimental at the zero lower bound. If instead policymakers announce a prolonged deviation from the Monetary led policy mix, inflation immediately increases because agents expect that debt will be inflated away. This, in turn, leads to a drop in the real interest rate that pushes the economy out of the recession. However, announcing a switch to the Fiscally led policy mix also results in an increase in macroeconomic volatility once the economy is out of the zero lower bound. The two results go together. The announcement is effective if and only if it is able to convince agents that the Fiscally led policy mix will prevail for a long time. As explained earlier, in this situation the macroeconomy is not insulated anymore with respect to fiscal disturbances.

Finally, if policymakers do not make any explicit announcements about the way they will deal with an increasing stock of debt once the economy will be out of the zero lower bound, agents are likely to form expectations that take into account all possible alternative scenarios. In this case, the model is able to rationalize why, despite the time spent at the zero lower bound, we have not observed deflation in the United States. Therefore, if deflation occurs or not at the zero lower bound depends on which exit strategy agents regard to be the most likely.

At the same time, across all the cases described before, *short-run* macroeconomic uncertainty turns out to be high. If agents expect a return to the Monetary led regime, uncertainty is high because both inflation and real economic activity are far from where they will be once out of the recession. Given that the timing of the end of the recession is unknown, the possibility of a large swing in real activity creates uncertainty. If instead the Fiscally led regime is expected to follow the recession, inflation and output move closer to their respective steady states, but agents come to realize that all shocks that are neutralized under the Monetary led regime will now be inflated away, again causing an increase in macroeconomic uncertainty. These results square well with recent contributions by Baker, Bloom, and Davis (2011), that show that policy uncertainty has increased since the beginning of the recession, Kitsul and Wright (2013), that point out that markets seem to swing between fear of inflation and fear of deflation, and Jurado, Ludvigson, and Ng (2013) and Bloom, Floetotto, Jaimovich, Saporta-Eksten, and Terry (2012) that document an overall increase in macroeconomic uncertainty during the recent recession.

While short-run uncertainty is high in both cases, the two scenarios differ in terms of the consequences for *long-run* uncertainty. If the Monetary led regime is expected to prevail, long-run uncertainty remains anchored because, in the long run, agents expect to be out of the recession and back to a stable macroeconomic environment. If the Fiscally led regime is announced instead, agents expect the volatile macroeconomic environment to prevail for a long time. Finally, if no announcement is made and agents attach similar probabilities to the two scenarios described before, uncertainty increases at all horizons.

Policy uncertainty can also result in perverse outcomes if it reflects a lack of coordination between the fiscal and monetary authorities. For example, the monetary authority might insist that once the economy is out the zero lower bound, inflation stability will be preserved, while the fiscal authority, in an attempt to stimulate private expenditure, might implicitly announce that no increase in taxation will follow the crisis. These two statements are *contradictory*, as the central bank cannot stabilize inflation without fiscal backing, and can lead to explosive dynamics for debt and inflation. Therefore, if agents expect that the crisis will be followed by a period during which the central bank tries to regain control of inflation without the support of the fiscal authority, high inflation and low growth could arise. To understand why, suppose that inflation is above target and the central bank reacts more than one-to-one to the deviation. The central bank is able to induce a recession that, together with the increase in real interest rates, leads to an increase in the debt-to-GDP ratio. If agents expect that the fiscal authority will eventually prevail, this expectation causes an increase in the amount of debt that will have to be inflated away, and inflation expectations go up. As a result, inflation increases rather than decreases. The expectation that these inflationary and contractionary spirals will prevail once the economy is *out* of the zero lower bound can then completely jeopardize the effectiveness of any attempt made by the two authorities to stimulate the economy *at* the zero lower bound.

In summary, a policy trade-off arises the moment that a large negative preference shock pushes monetary policy to the zero lower bound. The fact that the Monetary led regime results in a more stable macroeconomic environment in the long run provides support to those who are reluctant to explicitly abandon the policies that prevailed from the Volcker disinflation to the current crisis. Yet, the possibility of mitigating the recession by moving to the Fiscally led regime can explain why some policymakers and economists have suggested discontinuity with respect to the past. Finally, failure to resolve this latent conflict between short-run and long-run goals by policymakers could lead to perverse outcomes.

It is then natural to ask if it is possible to go beyond these two polar views. In other words, it would be interesting to see if it is possible to escape the Great Recession by generating an increase in inflation expectations via the fiscal mechanism outlined in this paper and at the same time preserve long-run macroeconomic stability. We show that in fact a way out exists: Policymakers could commit to inflate away only the portion of debt resulting from the exceptionally large recession.[2] This *shock specific rule* provides a sort of *automatic stabilizer*: The large negative preference shock can lead to a deep recession and a corresponding large increase in the debt-to-GDP ratio. The expectation that this extra fiscal burden is going to be inflated away determines a drop in the real interest rate that stimulates demand, reducing the size of the output contraction and the amount of debt that needs to be inflated away. This mechanism can be strong enough to prevent the economy from hitting the zero lower bound. Furthermore, given that the recession is now largely mitigated, the resulting increase in the debt-to-GDP ratio is small and so is the increase in inflation necessary to stabilize it.

At the same time, policymakers *never* changed their behavior with respect to the *pre-crisis stock of debt* and in response to other exogenous *business cycle disturbances* that are unlikely to push the economy to the zero lower bound. This has two very important consequences. First, the level of debt that existed before the crisis is irrelevant for the amount of inflation that is generated because it is still backed by future fiscal adjustments. Second, agents expect that all future fiscal imbalances will still be taken care of by the fiscal authority. Therefore, the proposed policy is successful in mitigating the recession and preserving long-run stability.

This paper is organized as follows. Section 2 reviews the related literature. Section 3 presents the model. Section 4 illustrates that the Monetary led regime leads to a stable macroeconomic environment. Section 5 shows that policy uncertainty can account for the lack of deflation and high macroeconomic uncertainty. Section 6 proposes the shock-specific policy response. Section 7 concludes.

[2] This policy has been advocated by Krugman (2013) and Rogoff (2008) among several others.

2 Related Literature

Our work is related to the vast theoretical literature on the zero lower bound. Wolman (1998), Fuhrer and Madigan (1994), Krugman (1998), and Orphanides and Wieland (1998, 2000) are among the first to study the zero lower bound and monetary policy in an intertemporal framework. Eggertsson and Woodford (2003) show that optimal monetary policy at the zero lower bound involves a commitment to generate future inflation. Eggertsson (2006) argues that such a policy can suffer from a time-inconsistency problem, while Eggertsson (2008), using a model in which taxation is costly, shows that President Franklin Delano Roosevelt was able to make the promise of future inflation credible by expanding fiscal deficits. Benhabib, Schmitt-Grohe, and Uribe (2001b) show that active monetary policy rules can lead to a liquidity trap, while Benhabib, Schmitt-Grohe, and Uribe (2002) explain how fiscal and monetary policies can be designed in order to rule out deflationary spirals. Correia, Farhi, Nicolini, and Teles (2012) show how distortionary taxes can be used to replicate the effects of negative nominal interest rates and completely circumvent the zero bound problem. Werning (2012) works in a deterministic environment and shows that the effectiveness of policies at the zero lower bound crucially depends on what agents expect after the constraint is not binding anymore. Fernandez-Villaverde, Guerron-Quintana, and Rubio-Ramirez (2011) show how supply-side policies may play a role in preventing an economy from hitting the zero lower bound. Schmitt-Grohe and Uribe (2012) present a model that can account for a recession associated with a protracted liquidity trap and a jobless recovery.

Our work differs from each of these papers in one or more of the following dimensions. First, we investigate the effects of policy uncertainty at the zero lower bound on macroeconomic uncertainty. In this respect, the paper is related to the literature on the macroeconomic effects of uncertainty (e.g., Bloom 2009; Fernandez-Villaverde, Guerron-Quintana, Rubio-Ramirez, and Martin Uribe 2011; Fernandez-Villaverde, Kuester, Guerron-Quintana, and Rubio-Ramirez 2011; Gilchrist, Sim, and Zakrajsek 2012; Williams 2012; and Basu and Bundick 2012). Second, we work in a stochastic environment (not perfect foresight/deterministic) with a standard new-Keynesian model augmented with a fiscal block. This makes our framework suitable for a quantitative assessment of the different exit strategies. Third, zero lower bound episodes are recurrent, and agents take this into account when forming expectations. In contrast, the literature generally considers situations in which the economy is currently at the zero lower bound and it will never be there again. Moreover, our paper proposes an alternative way for modeling recurrent zero-lower-bound events in microfounded dynamic stochastic general equilibrium (DSGE) models to those of Gust, Lopez-Salido, and Smith (2013) and Aruoba and Schorfheide (2013), and is related to the growing literature that allows for parameter instability in DSGE models (Justiniano and Primiceri 2008). Finally, our results are based on the possibility of generating an increase in inflation expectations through a change in the monetary/fiscal policy combination and do not require the use of distortionary taxation.

Other papers have addressed Bob Hall's puzzle (Ball and Mazumder 2011; King and Watson 2011; and Del Negro, Giannoni, and Schorfheide 2013). Unlike those contributions, this paper focuses on the consequences of uncertainty about future policymakers' behavior, showing that policy uncertainty in an otherwise standard New Keynesian model accounts for both the lack of deflation and the high uncertainty observed at the zero lower bound.

Our choice of working with regimes gives us the possibility of capturing the consequences of policy uncertainty and to compare different scenarios. Other authors have approached the problem of the zero lower bound from a different angle, i.e., by solving for optimal policies. While such an approach has provided the theoretical foundations of our understanding of the zero lower bound, it does not leave space for comparative analysis or the possibility of allowing for policy uncertainty in the moment that one optimal policy emerges. Accounting for policy uncertainty is important in light of a growing literature that argues that there were in fact changes in policymakers' behavior over the past 60 years (Clarida, Gali, and Gertler 2000; Lubik and Schorfheide 2004; Davig and Doh 2013; Fernandez-Villaverde, Guerron-Quintana and Rubio-Ramirez 2010; and Bianchi 2013). Finally, since the seminal contribution of Sims and Zha (2006), regimes have become a popular way to think about changes in policymakers' behavior in applied work.

This paper is related to a research agenda that aims to understand the role of fiscal policy in explaining changes in the reduced form properties of the macroeconomy. Using a Markov-switching DSGE model, Bianchi and Ilut (2012) show that the rise and fall of US inflation can be explained in light of a change in the monetary/fiscal policy mix that occurred a few years after the appointment of Paul Volcker as Federal Reserve Chairman. Bianchi and Melosi (2013) introduce the notion of *dormant shocks*, showing that a fiscal imbalance can lead to an increase in inflation many years after it occurred. This paper differs from the two aforementioned contributions across several dimensions. First, we here allow for the zero lower bound and study the consequences of policy uncertainty. Second, we outline that at the zero lower bound a policy trade-off between mitigating a large recession and preserving long run macroeconomic stability emerges. Finally, we show how policymakers can resolve this trade-off using a *shock-specific* rule.

Our work is then related to the study of the interaction between fiscal and monetary policies in determining inflation dynamics (Sargent and Wallace 1981; Leeper 1991; Sims 1994; Woodford 1994, 1995, 2001; Schmitt-Grohe and Uribe 2000; Cochrane 1998, 2001; among many others) and to the vast literature on fiscal multipliers (Blanchard and Perotti 2002; Mountford and Uhlig 2009; Uhlig 2010; Romer and Romer 2010; Mertens and Ravn 2011, 2013; Leeper, Walker, and Yang 2013; Misra and Surico 2013). Mertens and Ravn (2010) and Drautzburg and Uhlig (2011) use a DSGE model to study the fiscal multiplier when interest rates are stuck at the zero bound. Coibion, Gorodnichenko, and Wieland (2012) study the optimal inflation target in a new-Keynesian model in which the policy rate occasionally gets constrained by the zero lower bound.

3 The Model

We extend the basic new-Keynesian model employed by Clarida, Gali, and Gertler (2000), Woodford (2003), Gali (2008), and Lubik and Schorfheide (2004) to include a fiscal rule and the possibility of *recurrent* zero lower bound episodes.

3.1 A New-Keynesian model

The economy consists of a continuum of monopolistic firms, a representative household, and a monetary policy authority (or central bank). The household derives utility from consumption C_t and disutility from labor h_t:

$$E_0\left[\sum_{t=0}^{\infty}\beta^t \exp\left(d_t\right)\left[\log\left(C_t\right)-h_t\right]\right], \tag{1}$$

where β is the household's discount factor and the preference shock $d_t=\overline{d}_{\xi_t^d}$ can assume two values: high or low ($\overline{d}_h$ or $\overline{d}_l$). The variable ξ_t^d controls the regime in place and evolves according to the transition matrix H^d:

$$H^d=\begin{bmatrix} p_{hh} & 1-p_{ll} \\ 1-p_{hh} & p_{ll} \end{bmatrix},$$

where $p_{ji}=P\left(\xi_{t+1}^d=j|\xi_t^d=i\right)$. This specification is in the spirit of Christiano, Eichenbaum, and Rebelo (2011). However, in the current setup shocks to preferences are assumed to be recurrent, and agents take into account that these episodes can lead to unusual policymakers' responses, as discussed later on. The household budget constraint is given by:

$$P_tC_t+B_t+P_tT_t=P_tW_th_t+R_{t-1}B_{t-1}+P_tD_t, \tag{2}$$

where B_t represents bond holdings, D_t captures dividends paid by firms, W_t is the real wage, T_t is a net lump sum tax, P_t is the price level, and R_t is the one-period gross interest rate.

Each of the monopolistically competitive firms faces a downward-sloping demand curve:

$$Y_t(j)=\left(P_t(j)/P_t\right)^{-1/\upsilon}Y_t, \tag{3}$$

where $P_t(j)$ is the price chosen by firm j and the parameter $1/\upsilon$ is the elasticity of substitution between two differentiated goods. The firms take as given the general price level P_t and level of real activity Y_t. Whenever a firm wants to change its price, it faces quadratic adjustment costs represented by an output loss:

$$AC_t(j) = (\varphi/2)\left(P_t(j)/P_{t-1}(j) - \Pi\right)^2 Y_t(j), \tag{4}$$

where Π is the deterministic steady-state level for gross inflation.

The firm chooses the price $P_t(j)$ to maximize the present value of future profits:

$$E_0\left[\sum_{t=0}^{\infty} Q_t\left(P_t(j)Y_t(j)/P_t - W_t h_t(j) - AC_t(j)\right)\right],$$

where Q_t is the household's stochastic discount factor. Labor is the only input in a linear production function, $Y_t(j) = A_t h_t(j)$, where total factor productivity $z_t = \ln(A_t/A)$ follows an autoregressive process: $z_t = \rho_z z_{t-1} + \sigma_z \epsilon_{z,t}$, $\epsilon_{z,t} \sim N(0,1)$.

The central bank follows the rule:

$$\frac{R_t}{R} = \left(1 - Z_{\xi_t^d}\right)\left(\frac{R_{t-1}}{R}\right)^{\rho_R}\left[\left(\frac{\Pi_t}{\Pi}\right)^{\psi_{\pi,\xi_t^p}}\left(\frac{Y_t}{Y_t^n}\right)^{\psi_y}\right]^{(1-\rho_R)} e^{\sigma_R \epsilon_{R,t}} + \frac{Z_{\xi_t^d}}{R}$$

where $\epsilon_{R,t} \sim N(0,1)$, R is the steady-state gross nominal interest rate, Y_t^n is natural output, the level of output that would prevails in absence of nominal rigidities, Π is the target/steady-state level for gross inflation, the variable ξ_t^p captures the monetary/fiscal policy combination that is in place at time t, and the dummy variable $Z_{\xi_t^d}$ controls if the economy is in or out of the zero lower bound. When $\overline{d}_{\xi_t^d} = \overline{d}_h$, the economy is out of the zero lower bound and monetary and fiscal policies are not constrained ($Z_{\xi_t^d} = 0$). In this case the evolution of the policy mix can be described by the two-regime Markov switching process ξ_t^p. The properties of the transition matrix and of the regimes will be described later. When $\overline{d}_{\xi_t^d} = \overline{d}_l$, the zero lower bound is binding, given that a standard Taylor rule would require a negative nominal interest.[3] In this case, policymakers abandon the policy mix that they were following and set the net nominal interest rate to zero ($Z_{\xi_t^d} = 1$).

The government budget constraint is given by:

$$b_t = b_{t-1}\left(Y_t\Pi_t/Y_{t-1}\right)^{-1} R_{t-1} - s_t,$$

[3] We assume that whenever the negative preference shock hits, policymakers move to the zero-lower-bound regime described later on and we choose the parameters values in a way that the zero lower bound is binding with high probability when $\overline{d}_{\xi_t^d} = \overline{d}_l$. Our approach to model the zero lower bound differs from the conventional one (e.g., see Eggertsson and Woodford 2003; Benhabib, Schmitt-Grohe, and Uribe 2002), which implies $R_t = \max(0, R_t^*)$, where R_t^* is the interest rate implied by the Taylor rule. While our approach cannot rule out that there exist some unlikely states of the world in which the nominal rate R_t assumes negative values, it has the advantage of making the model tractable and allows us to study the consequences of policy uncertainty.

where $b_t = B_t / (P_t Y_t)$ and $s_t = S_t / (P_t Y_t)$ are the debt-to-GDP ratio and the primary-surplus-to-GDP ratio, respectively. We assume that the government only moves lump-sum taxes and provides a subsidy. In other words, we exclude government purchases and we assume that the primary surplus coincides with net lump-sum taxes ($T_t = S_t$). This will allow us to completely isolate the effects of fiscal shocks deriving from the lack of fiscal discipline. Introducing government purchases (G_t) would not modify the mechanism outlined here, but would make the interpretation of the results less immediate. The fiscal authority moves the primary surplus according the following rule

$$
\begin{aligned}
(s_t - s) &= \delta_{b,\xi_t^p} (b_{t-1} - b) + \delta_y (y_t - y_t^n) + x_t, & (5) \\
x_t &= \rho_x x_{t-1} + \sigma_x \epsilon_{x,t}, \ \epsilon_{x,t} \sim N(0,1), & (6)
\end{aligned}
$$

where $y_t = \ln(Y_t)$ and $y_t^n = \ln(Y_t^n)$. We will refer to $\epsilon_{x,t}$ as a fiscal shock. Notice that the parameter controlling the response of primary surpluses to debt, δ_{b,ξ_t^p}, is also indexed with respect to ξ_t^p.

3.2 Linearization

The model is solved and linearized around the deterministic steady state. We first compute the ergodic mean $\overline{d}$ for the preference shock and verify that the zero lower bound does not bind in this case. We then compute the steady state associated with this value and linearize around it. From now on, all variables should be interpreted as deviations from steady state.[4]

The private sector can be described by the following system of equations:

$$
\begin{aligned}
\widetilde{\pi}_t &= \beta E_t(\widetilde{\pi}_{t+1}) + \kappa(\widetilde{y}_t - z_t), & (7) \\
\widetilde{y}_t &= E_t(\widetilde{y}_{t+1}) - \left(\widetilde{R}_t - E_t(\widetilde{y}_{t+1})\right) + \widetilde{d}_t - E_t\left(\widetilde{d}_{t+1}\right), & (8) \\
\widetilde{d}_t &= \widetilde{\overline{d}}_{\xi_t^d}, & (9) \\
z_t &= \rho_z z_{t-1} + \sigma_z \epsilon_{z,t}, \ \epsilon_{z,t} \sim N(0,1), & (10)
\end{aligned}
$$

where $\widetilde{d}_t = d_t - \overline{d}$ and $\widetilde{\overline{d}}_{\xi_t^d} = \overline{d}_{\xi_t^d} - \overline{d}$. Inflation dynamics are described by the expectational Phillips curve (7) with slope κ. Equation (8) is the linearized intertemporal Euler equation describing the households' optimal choice of consumption and bond holdings.

The linearized government budget constraint is given by:

$$
\widetilde{b}_t = \beta^{-1}\widetilde{b}_{t-1} + b\beta^{-1}\left(\widetilde{R}_{t-1} - \widetilde{\pi}_t - \Delta\widetilde{y}_t\right) - \widetilde{s}_t, \tag{11}
$$

[4]We linearize with respect to debt and primary surpluses, given that these variables can change sign, while we log-linearize with respect to all the others. Appendix A.1 provides additional details on how we handle the Markov-switching preference shock.

where $\widetilde{b}_t$ and $\widetilde{s}_t$ represent now debt and surplus in terms of GDP in linear deviations from the steady state. The fiscal policy mix is given by:

$$\widetilde{s}_t = \delta_{b,\xi_t^p}\widetilde{b}_{t-1} + \delta_y\left(\widetilde{y}_t - z_t\right) + x_t, \tag{12}$$

$$x_t = \rho_x x_{t-1} + \sigma_x \epsilon_{x,t}, \;\; \epsilon_{x,t} \sim N\left(0,1\right), \tag{13}$$

while the linearized monetary policy policy mix is:

$$\begin{aligned}\widetilde{R}_t = & \left[1 - Z_{\xi_t^d}\right]\left[\rho_R \widetilde{R}_{t-1} + (1-\rho_R)\left(\psi_{\pi,\xi_t^p}\widetilde{\pi}_t + \psi_y\left[\widetilde{y}_t - z_t\right]\right) + \sigma_R \epsilon_{R,t}\right] \\ & - Z_{\xi_t^d}\log\left(R\right),\end{aligned} \tag{14}$$

where $\epsilon_{R,t} \sim N\left(0,1\right)$. Therefore,

$$\widetilde{R}_t = \rho_R \widetilde{R}_{t-1} + (1-\rho_R)\left(\psi_{\pi,\xi_t^p}\widetilde{\pi}_t + \psi_y\left[\widetilde{y}_t - z_t\right]\right) + \sigma_R \epsilon_{R,t}, \tag{15}$$

if the economy is out of the zero lower bound ($Z_{\xi_t^d} = 0$), while $R_t = -\log\left(R\right)$ if the zero lower bound binds ($Z_{\xi_t^d} = 1$).

3.3 Regime changes

To characterize policymakers' behavior out of the zero lower bound, we will make use of the partition of the parameter space introduced by Leeper (1991). We can distinguish four regions (Table 1) based on the properties of the model under fixed coefficients. When the values of model parameters are fixed, the two policy rules are key in determining the existence and uniqueness of a solution. There are two determinacy regions. The first region, Active Monetary/Passive Fiscal (AM/PF), is the most familiar one: The Taylor principle is satisfied and the fiscal authority moves taxes in order to keep debt on a stable path: $\psi_\pi > 1$ and $\delta_b > \beta^{-1} - 1$. To grasp the intuition behind this result, substitute the tax rule in the law of motion for government debt (assuming for simplicity $\rho_x = 0 = \delta_y$) and isolate the resulting coefficient for lagged government debt:

$$\widetilde{b}_t = \left(\beta^{-1} - \delta_b\right)\widetilde{b}_{t-1} + b\beta^{-1}\left(\widetilde{R}_{t-1} - \widetilde{\pi}_t - \Delta\widetilde{y}_t\right) - \sigma_s \epsilon_{s,t},$$

Intuitively, in order to guarantee stability of government debt, we need this coefficient to be smaller than one ($\beta^{-1} - \delta_b < 1$), so that debt is mean reverting. This in turn requires the coefficient on debt in the tax rule to satisfy the condition $\delta_b > \beta^{-1} - 1$. Therefore, we can think of fiscal policy as passive to the extent that it *passively* accommodates the behavior of the monetary authority ensuring debt stability. We will refer to this policy combination as *Monetary led regime.*

	Active Fiscal (AF)	Passive Fiscal (PF)
Active Monetary (AM)	No Solution	**Determinacy**
Passive Monetary (PM)	**Determinacy**	Indeterminacy

Table 1: Partition of the parameter space according to existence and uniqueness of a solution (Leeper 1991).

The second determinacy region, Passive Monetary/Active Fiscal (PM/AF), is less familiar and corresponds to the case in which the fiscal authority is not committed to stabilizing the process for debt: $\delta_b < \beta^{-1} - 1$. Now it is the monetary authority that *passively* accommodates the behavior of the fiscal authority, disregarding the Taylor principle and allowing inflation to move in order to stabilize the process for debt: $\psi_\pi < 1$. Under this regime, even in the absence of distortionary taxation, shocks to net taxes can have an impact on the macroeconomy as agents understand that they will not be followed by future offsetting changes in the fiscal variables. We will label this policy combination as *Fiscally led regime*. Finally, when both authorities are active (AM/AF) no stationary equilibrium exists, whereas when both of them are passive (PM/PF) the economy is subject to multiple equilibria.[5]

In the benchmark model, when the preference shock is high ($\xi_t^d = h$), the economy is out of the zero lower bound ($Z_{\xi_t^d} = 0$) and the evolution of policymakers' behavior is captured by a two-regime Markov chain that evolves according to the transition matrix H^p:

$$H^p = \begin{bmatrix} p_{MM} & 1 - p_{FF} \\ 1 - p_{MM} & p_{FF} \end{bmatrix},$$

where $p_{ji} = P\left(\xi_{t+1}^p = j | \xi_t^p = i\right)$. This transition matrix is supposed to capture the stochastic outcome of a game between the monetary and fiscal authorities that is not explicitly modeled in this paper. Regime M is the *Monetary led regime*, under which the Taylor principle is satisfied and fiscal policy accommodates the behavior of the monetary authority. In terms of policy parameters, this implies that $\psi_{\pi,M} = \psi_\pi^A > 1$ and $\delta_{b,M} = \delta_b^P > \beta^{-1} - 1$. Regime F is the *Fiscally led regime*. Under such a regime, the central bank reacts less than one-for-one to inflation and the fiscal authority does not move surpluses in response to movements in government debt: $\psi_{\pi,F} = \psi_\pi^P < 1$ and $\delta_{b,F} = \delta_b^A < \beta^{-1} - 1$.

When the low value for the preference shock occurs ($\xi_t^d = l$), the zero lower bound becomes binding ($Z_{\xi_t^d} = 1$), and policymakers' behavior is now constrained. In this third policy combination the nominal interest rate is set to zero and the fiscal authority disregards the level of debt: $\delta_Z = 0$. Notice that the zero-lower-bound policy mix can be considered as an extreme version of the Fiscally led policy mix. However, while out of the zero lower bound, switches

[5] Benhabib, Schmitt-Grohe, and Uribe (2001a) show that if money is assumed to enter or not preferences and technology matters for whether a particular monetary/fiscal regime is conducive to determinacy. Our setting is standard in this respect and Leeper's (1991) partition applies.

Parameter	Value	Parameter	Value	Parameter	Value
$\psi_{\pi,M}$	2.00	ψ_y	0.10	$100\sigma_R$	0.20
$\psi_{\pi,F}$	0.80	ρ_R	0.75	$100\sigma_x$	0.50
$\delta_{b,M}$	0.03	δ_y	0.50	$100\sigma_z$	0.70
$\delta_{b,F}, \delta_{b,Z}$	0.00	ρ_z	0.90	$\overline{d}_h$	0
Z_h	0	ρ_x	0.90	$\overline{d}_l$	$-.1$
Z_l	1	b	1.00	p_{hh}	98%
p_{MM}	99%	κ	0.035	p_{ll}	80%
p_{FF}	99%	β	0.995		

Table 2: Parameter choices of the DSGE parameters and of the transition matrix elements.

to the Fiscally led regime capture deliberate choices of policymakers, the adoption of the zero-lower-bound regime is induced by an exogenous negative preference shock that prompts the fiscal authority to forgo fiscal adjustments to counter the effects of a deep recession. Once the preference shock is back to its high value ($\xi_t^d = h$), policymakers' behavior is not constrained anymore.

It is worth emphasizing that even if the zero lower bound imposes a constraint on policymakers' behavior, agents' beliefs are not constrained. Therefore, announcements about the exit strategy and policy uncertainty are going to be key to understand what occurs at the zero lower bound. To capture this feature, the effective number of regimes at the zero lower bound needs to be expanded in order to reflect agents' beliefs about policymakers' future behavior. For example, if we want to model an economy in which from the zero lower bound policymakers can decide to move to either the Fiscally led regime or the Monetary led regime, we need to introduce two zero-lower-bound regimes that simply differ in terms of what the announced exit strategy is. Therefore, for each of the zero-lower-bound regimes we will have to specify the entering probability, the probability of moving to another zero-lower-bound regime, and policymakers' exit strategy. We assume that these are captured by the matrices H^i, H^z, and H^o, where i, z, and o stand for *in*, *at* the zero lower bound, and *out* of the zero lower bound, respectively. Later on we will see that different exit strategies can substantially change the dynamics of the model.

In summary, the evolution of policymakers' behavior can be described by a transition matrix obtained by combining the transition matrix H^d, which describes the evolution of the preference shock; the transition matrix H^p, which describes policymakers' behavior out of the zero lower bound; the matrix H^i, which describes the probability of entering each of the zero-lower-bound regimes; the matrix H^z, which describes the probability of moving across the zero-lower-bound regimes; and the matrix H^o, which describes the exit strategy for each of the zero-lower-bound regimes:

$$H = \left[\begin{array}{cc} p_{hh} H^p & (1 - p_{ll}) H^o \\ (1 - p_{hh}) H^i & p_{ll} H^z \end{array} \right].$$

For each of the models considered in this paper, Appendix A.2 reports the corresponding choice for the matrix H. The other parameter values for the model are chosen in line with the estimates obtained by Bianchi and Ilut (2012) and are reported in Table 2.[6] In our benchmark model, monetary and fiscal policies move together. Our setup can easily accommodate cases in which only one of the two authorities changes behavior. We will consider some of these cases in Section 5.

The model can be solved with any of the solution methods developed for Markov–switching DSGE models. We use the solution method of Farmer, Waggoner, and Zha (2009). It is worth emphasizing that in our model, agents form expectations while taking into account the possibility of entering the zero lower bound. Furthermore, they understand that entering the zero lower bound is an event induced by an exogenous shock that can modify policymakers' behavior even once the constraint stops binding. In other words, our approach allows us to model recurrent zero-lower-bound episodes and to capture the impact of different exit strategies for policymakers' behavior at the zero lower bound.

4 No Zero-Lower-Bound Episodes

In this section, we show that when the possibility of zero-lower-bound episodes is ruled out, the Monetary led regime leads to a more stable macroeconomic environment. The model parameters are as described in Table 2, with the only exception that the preference shock is always assumed to be at the ergodic mean $\overline{d}$. Later on we will relax this assumption in order to allow for recurrent zero-lower-bound episodes.

4.1 Impulse responses and policymakers' behavior

In order to understand the differences between the Fiscally led and the Monetary led regimes, Figure 1 reports the impulse responses to a primary deficit shock. Impulse responses are computed conditionally on one regime being in place over the entire horizon. Nevertheless, model dynamics reflect the possibility of regime changes. When the Fiscally led regime is in place, agents understand that in the near future the probability of a fiscal adjustment in

[6] For the sake of simplicity, we assume that under the zero-lower-bound policy mix and the Fiscally-led policy mix, policymakers completely disregard movements in the debt-to-GDP ratio. This choice has the advantage of leading to sharp results, making the analysis that will follow clearer. Our conclusions would be virtually unchanged if we assumed that the response to the debt-to-GDP ratio is larger than zero but strictly lower than the threshold $\left(\beta^{-1} - 1\right)$.

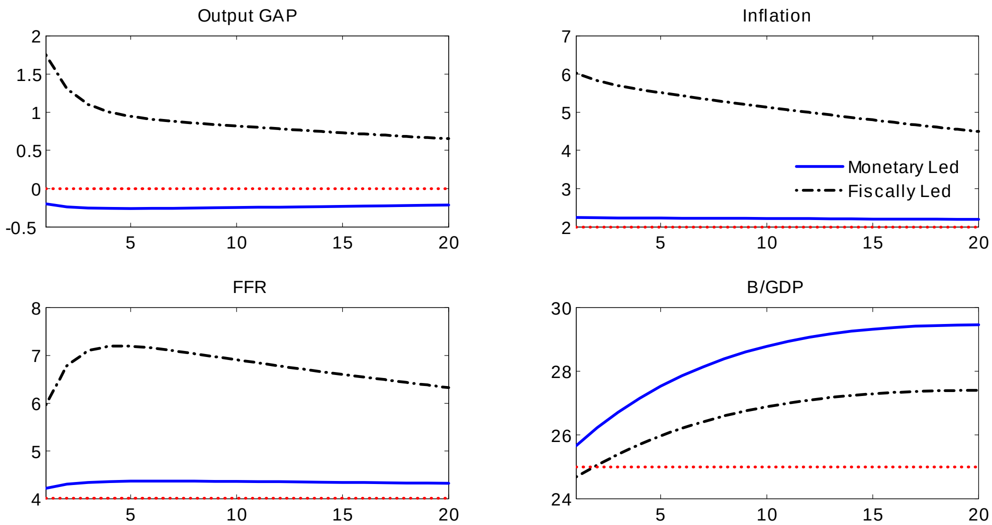

Figure 1: **Impulse responses to a primary deficit shock conditional on a regime being in place over the relevant horizon.**

response to the current increase in the primary deficit is fairly low. This determines an increase in inflation that is made possible by the accommodating behavior of the Monetary authority. Given that the Taylor principle does not hold, the response of the nominal interest is less than one-to-one. The resulting decline in the real interest determines an increase in real activity. The debt-to-GDP ratio is then stabilized because of the fall in the real interest rate and the faster growth in real economic activity. The macroeconomy is therefore not insulated with respect to fiscal imbalances even if taxation is non-distortionary. Under the Monetary led regime the primary deficit shock triggers only a negligible increase in inflation because the fiscal authority is expected to implement the necessary fiscal adjustments. However, the response of inflation is not exactly zero because agents form expectations by taking into account the possibility of moving to the Fiscally led regime. As a result, a high level of debt determines some slight inflationary pressure even when the Monetary led regime is in place, in line with the results obtained by Bianchi and Ilut (2012) in an estimated model, Davig and Leeper (2006) in a calibrated model, and Davig, Chung, and Leeper (2007) in an analytical example. Given that the Taylor principle holds, the central bank reacts more than one to one to the increase in inflation. The result is a prolonged period of negative output gaps that last as long as the debt-to-GDP ratio is not fully repaid.

In summary, two important lessons can be drawn from this exercise. First, under the Monetary led regime, the macroeconomy is largely insulated with respect to fiscal imbalances. Second, as long as agents are aware of regime changes, even under the Monetary led regime the macroeconomy is not *completely* insulated and fiscal imbalances have inflationary pressure. This inflationary pressure would disappear only if the Monetary led policy mix were the only possible one.

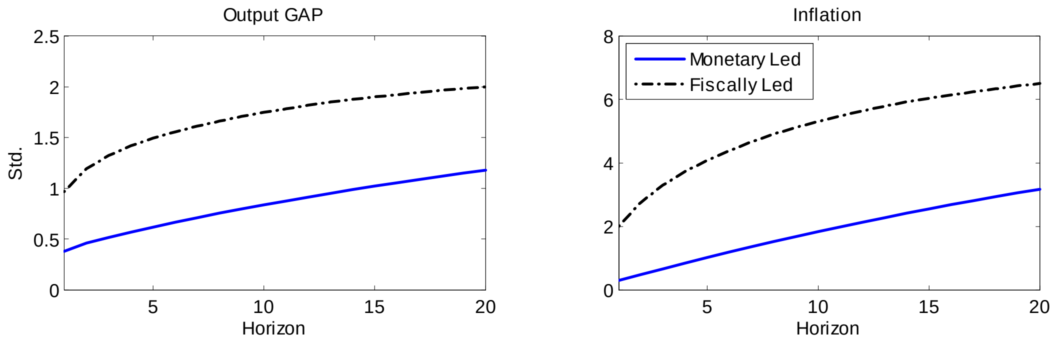

Figure 2: **Evolution of uncertainty taking into account the possibility of regime changes for different starting regimes.**

4.2 Uncertainty and policymakers' behavior

In this subsection, we show that the Monetary led regime leads to a more stable macroeconomic environment. For each regime, Figure 2 reports the evolution of uncertainty at different horizons, from 1 quarter to 5 years. This measure of uncertainty is computed while taking into account the possibility of regime changes and the occurrence of Gaussian shocks by using the methods described in Bianchi (2013a). For a variable X_t and an horizon h, it corresponds to the conditional standard deviation $sd_t(X_{t+h})$.

When policymakers follow the Monetary led policy mix, agents anticipate that with high probability future fiscal imbalances will be neutralized through the actions of the fiscal authority. This leads to a reduction in macroeconomic uncertainty. At the same time, the central bank behaves according to the Taylor principle, leading to a further reduction in volatility. If instead policymakers follow the Fiscally led regime, uncertainty increases at all horizons. This is because of two reasons. First, the central bank reacts less aggressively to economic fluctuations given that the Taylor principle is not satisfied. Second, agents anticipate that all fiscal imbalances that are largely neutralized when policymakers follow the Monetary led regime will now strongly affect inflation and real economic activity. Inflation, not taxation, will be mainly adjusted to stabilize the path for debt. In other words, the macroeconomy is heavily affected by fiscal imbalances when the policymakers adopt a Fiscally led policy mix. As a result, under this policy mix, uncertainty is higher at every horizon because agents expect all future fiscal imbalances to be largely inflated away.

The level of uncertainty under the Monetary led regime is higher than what would be if the Monetary led regime were the only possible one. This is for two reasons. First, as shown in the previous subsection, the macroeconomy is not fully insulated with respect to fiscal imbalances because agents always discount the possibility of a switch to the Fiscally led policy mix. This effect is present at all horizons. Second, uncertainty is computed by taking into account that in the future the economy might in fact switch to the Fiscally led policy mix. This effect is increasing with the time horizon. In fact, as the horizon approaches to infinity, the regime probabilities converge to their ergodic values and so does uncertainty.

In summary, the model predicts that when zero-lower-bound episodes are ruled out, the Monetary led regime is generally preferable because it leads to a stable macroeconomic environment. We obtain this result because under the Monetary led regime the Taylor principle is satisfied and the macroeconomy is largely insulated with respect to fiscal imbalances. Furthermore, a further reduction in macroeconomic uncertainty would occur if agents regarded the Monetary led regime as the only possible one, since the macroeconomy would be completely insulated with respect to fiscal imbalances. To the extent that macroeconomic stability is desirable, countries with a strong reputation for fiscal discipline will benefit from a more favorable outcome *during regular times.*

5 The Policy Trade-off

While the Monetary led regime leads to a more stable macroeconomic environment during regular times, extraordinary events can make deviating from such a regime desirable. One of such events is a significant drop in aggregate demand, which is induced by the discrete preference shock $\widetilde{\widetilde{d}}_l$. In this section, we will first review the standard result of the new-Keynesian literature that predicts that such a large contraction in aggregate demand should lead to deflation as a result of the nominal interest rate hitting the zero lower bound. Then, we will provide a possible explanation for why this prediction of the benchmark model does not seem to be in line with US data. Specifically, we will show that if agents are uncertain about how policymakers will deal with the large stock of debt arising from a deep recession, deflation is not a necessary implication of entering the zero lower bound, while high uncertainty is. This will also allow us to outline the policy trade-off that arises at the zero lower bound: mitigating the large recession or preserving long-run macroeconomic stability.

5.1 A useful benchmark: The textbook new-Keynesian model

Consider the model described in Section 3, assuming that policymakers' behavior is *always* characterized by the Monetary led regime. Suppose that the economy is hit by the negative preference shock ($\xi_t^d = l$) at time 10 and switches back to the high value ($\xi_t^d = h$) at time 20. This preference shock determines a large contraction in output as illustrated in Figure 3. In this situation the drop in the output gap and inflation is so large that the desired monetary policy interest rate becomes negative. This is exactly when the zero-lower-bound constraint becomes binding. The black dashed line in Figure 3 illustrates what would happen if the central bank could set a negative nominal interest rate. Notice that the contraction in output would

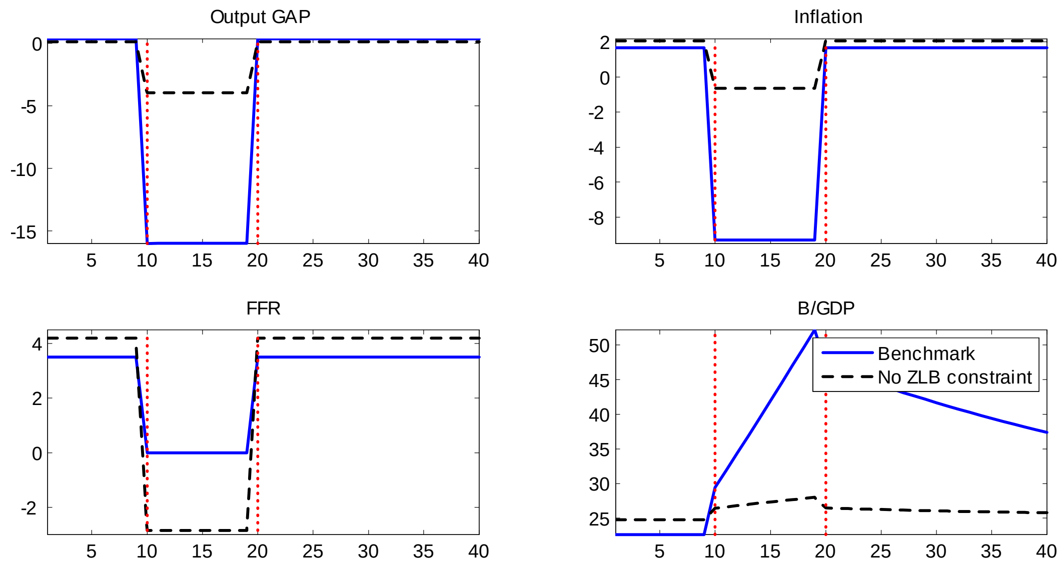

Figure 3: **Benchmark new-Keynesian model and the zero lower bound.** This figure illustrates the behavior of an economy in which policymakers always follow the Monetary led regime. The blue solid line imposes the zero-lower-bound constraint, while the black dashed line does not. All Gaussian shocks (i.e., $\epsilon_{z,t}$, $\epsilon_{x,t}$, and $\epsilon_{R,t}$) are set to zeros at all times in these simulations. The vertical red dotted lines indicate the period in which the economy is at the zero lower bound.

be relatively small and there would be little effect on inflation and on the debt-to-GDP ratio. Instead, the blue solid line imposes the zero-lower-bound constraint.[7] The fact that in reality the central bank cannot set a negative nominal interest rate has pervasive consequences for the law of motion of the economy. First of all, the drop in the output gap is substantially larger, because the implied real interest rate is too high. At the same time, the economy experiences strong deflation. Finally, a large stock of debt is accumulated as a result of the automatic adjustment of the primary surplus to economic conditions.

It is worth pointing out that agents completely understand the structure of the economy. This implies that while at the zero lower bound they know that there is a positive probability of exiting, but they do not know when this will occur. At the same time, in our setup, agents are fully aware that such a large negative preference shock is a recurrent event. Therefore, the model dynamics *out* of the zero lower bound are also affected. Agents realize that in every period there is a (small) probability of observing a large contraction in inflation and real economic activity. This feature determines deflationary pressures out of the zero lower bound. Thus, as shown in Figure 3 inflation is slightly lower than what would arise if the zero-lower-bound constraint is not imposed. Given that the Taylor principle is satisfied, the central bank tries to correct these deflationary pressures by keeping the interest rate relatively lower. This corrective action leads to a slightly positive output gap. As a result, the debt-to-GDP ratio is

[7] Technically, imposing the zero-lower-bound constraint boils down to assuming that whenever the negative preference shock is realized the monetary policy policy rule enters the zero-lower-bound regime ($Z_{\xi_t^p} = 1$).

slightly lower than what is observed when the zero-lower-bound constraint is not imposed.

5.2 Uncertainty and announcements

In this subsection, we will illustrate that while uncertainty is an inherent implication of entering the zero lower bound, deflation is not. This is because a deep recession leads to a large accumulation of debt that provides inflationary pressure. Furthermore, as it will be shown here, the recession can be mitigated by inflating away all or part of debt. As a result, agents are going to be very uncertain about policymakers' behavior and, consequently, future economic outcomes.

In what follows, we assume that agents recognize that the zero-lower-bound regime is triggered by an exogenous event over which policymakers have no control. In this situation, agents pay attention to policy announcements to get some guidance about policymakers' future behavior. We will see that policymakers can mitigate the recession at the cost of raising long run macroeconomic volatility.

5.2.1 Coordinated announcements

In the past three years, the Federal Reserve has kept the federal funds rate at zero. As shown earlier, in the textbook new-Keynesian model once the policy rate hits the zero lower bound, deflation occurs. A large preference shock that induces consumers to drastically reduce demand can lead to this situation. Agents want to save more, so they reduce consumption and demand falls; consequently, real economic activity and inflation fall. If the drop is large enough, the desired policy interest rate becomes negative and the best that the central bank can do is to drive the interest rate to zero. Therefore, the real interest rate is in fact too high compared with what would be desirable, and the economy can experience a very large drop in real economic activity and deflation.

These basic predictions of the benchmark new-Keynesian model seem at odds with US data that show that inflation has been fluctuating around the implicit Federal Reserve's inflation target. In this subsection, we show that the behavior of inflation during this period is consistent with the high uncertainty that surrounds how policymakers will behave in the future. Uncertainty often characterizes exceptional events and the Great Recession is not an exception. Policymakers do not seem to have outlined a clear exit strategy yet. Arguably, this creates some uncertainty about the way they will deal with the large stock of debt that originated from the current crisis. As discussed earlier, the outcomes of the policy implemented at the zero lower bound critically depend on what agents expect to happen once the economy has exited the zero lower bound.

We consider an economy that is hit by a large negative preference shock that pushes the economy to the zero lower bound and lasts for ten periods. We assume that before the shock

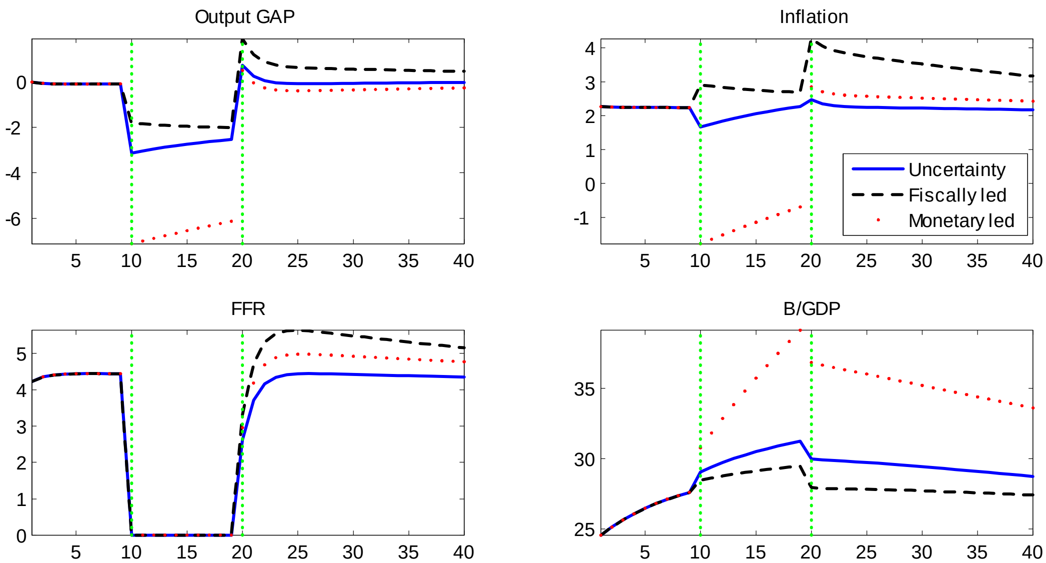

Figure 4: **Macroeconomic Dynamics with Coordinated Announcements**: The figure reports the effects of a large negative preference shock that forces the interest rate to the zero lower bound. At the time the preference shock hits, the economy has a stock of debt above the steady state resulting from an increase in primary deficits. Three cases are considered for the exit strategy. In the first case ("Monetary led"), policymakers announce a return to the Monetary led regime; in the second case ("Fiscally led"), a switch to the Fiscally led regime is announced; and in the third case ("Uncertainty"), no announcement about the exit strategy is made and agents attach equal probabilities to the other two strategies. The vertical green dotted lines indicate the period in which the economy is at the zero lower bound.

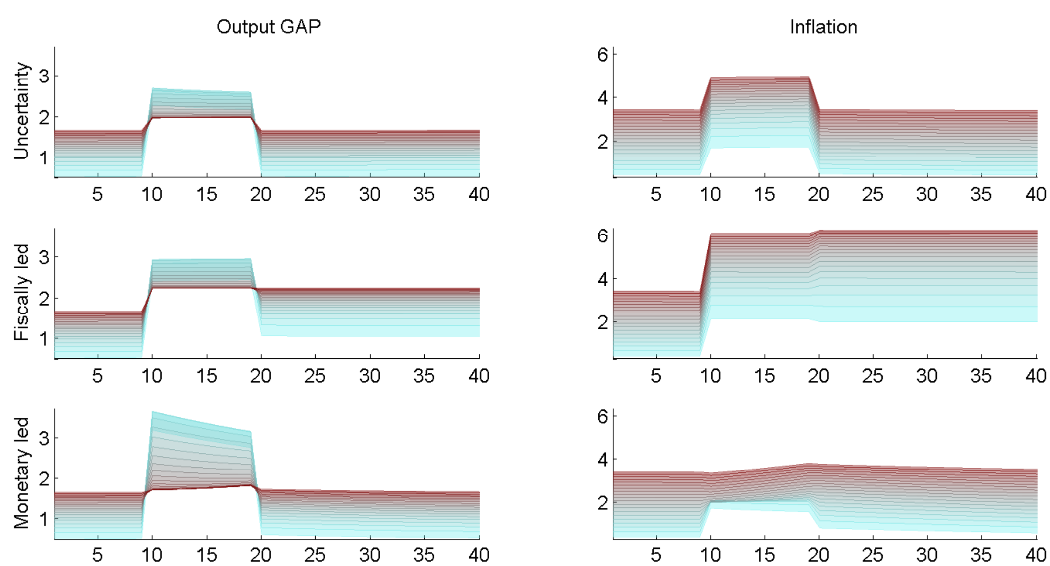

Figure 5: **Evolution of Uncertainty with Coordinated Announcements:** The figure reports the evolution of uncertainty for an economy with an above-steady-state stock of debt that enters the zero lower bound regime under the Monetary led regime. Three cases are considered for the exit strategy. In the first case (the bottom panels), policymakers announce a return to the Monetary led regime; in the second case (the middle panels), a switch to the Fiscally led regime is announced; in the third case (the top panels), no announcement is made about the exit strategy and agents attach equal probabilities to the other two strategies. The zero-lower-bound period lasts from period $t = 11$ through period $t = 20$.

occurred, policymakers were following the Monetary led regime and the stock of debt was slightly above its steady-state value. The positive stock of debt is created with a primary deficit shock. These assumptions are meant to create a scenario in line with US data, at least from a qualitative point of view. It is worth pointing out that initially the rising stock of debt has a negligible effect on the macroeconomy because policymakers are assumed to be behaving according to the Monetary led regime.

We analyze three different scenarios concerning policymakers' behavior. In the first scenario, policymakers announce that fiscal discipline will be abandoned for a long time once out of the zero lower bound. In the second scenario, policymakers announce that once the economy is out of the zero-lower-bound period, fiscal discipline will be restored. Finally, in the third case, no exit strategy is clearly announced and agents attach equal probabilities to the two exit strategies. In all cases, we assume that agents take into account that uncertainty could be resolved or that announcements could be changed.

Figure 4 reports the responses of the variables in an economy that is hit by the large negative preference shock ($\xi_t^d = l$) at time 10 and switches back to the high preference shock at time 20. It is worth emphasizing that agents are fully aware of the structure of the model. Therefore, they understand that in response to the negative preference shock policymakers have switched to one of the zero-lower-bound regimes. However, agents do not know *when* the preference shock will return to the high value ($\xi_t^d = h$) and are aware that in the future zero lower bound episodes might occur again. In other words, unlike previous contributions in the literature, we do not impose perfect foresight or an absorbing state for $\xi_t^d = h$. Finally, agents do not necessarily know which exit strategy will be adopted by policymakers. As a result, announcements by policymakers play a critical role by steering agent's expectations about the likely exit strategy.

If policymakers announce that fiscal discipline will be abandoned (black dashed line) agents expect that the preexisting stock of debt and the additional amount of debt accumulated during the recession will be inflated away. Therefore, they revise upward their inflation expectations and, consequently, inflation increases today through the expectation channel. Notice that the recession is in this case substantially mitigated.

If instead policymakers explicitly announce that the stance toward fiscal discipline has not changed and that after the economy exits the zero lower bound they will resume the same policies that characterized the pre-crisis period, the economy enters a deep recession and deflation arises (red dotted line). The outcomes for this case are qualitatively in line with the traditional view about the zero lower bound. The positive fiscal imbalance has little effect on real economic activity and policymakers are not able to avoid a large recession. However, the drop in real activity and inflation is more contained than in the case of the benchmark new-Keynesian model presented in Subsection 5.1. This is because the expectations of rapid debt accumulation determine inflationary pressures even if agents expect that the Monetary led regime will follow the end of the zero lower bound. As discussed in Subsection 4.1, agents are aware of regime changes and hence know that there is a non-zero probability that the Fiscally-led policy mix will follow the announced policy shortly after the economy will be out of the zero lower bound.

The most relevant case from an empirical point of view is represented by the third scenario, whose macroeconomic implications are illustrated by the solid blue line. When policymakers do not make any announcement, agents are uncertain about which exit strategy will in fact prevail. The recession is mitigated and inflation remains very close to its target value. This is because agents attach similar probabilities to two very different outcomes: In one case, agents expect inflation stability to be preserved, while in the other case they expect a large spur of inflation in order to stabilize debt. Note that as debt keeps increasing, inflation slowly goes up in response to the increasing inflationary pressure. Finally, once the economy is out of the zero lower bound the exit strategy is revealed. We only report the case in which policymakers revert to the Monetary led policy mix and inflation goes back to the steady state, but there is an equally likely scenario in which policymakers move to the Fiscally led regime and inflation increases.

Figure 5 illustrates the evolution of uncertainty across different horizons for the three scenarios presented above and using the same simulation for the preference shocks. We consider horizons from 1 quarter (light blue) to 5 years (dark red). Independently from what policymakers announce, short run uncertainty sharply increases when entering the zero lower bound. However, the sources of uncertainty are completely different across the different simulations. When the return to Monetary led policy is announced, short run uncertainty is high because both real activity and inflation are very far from where they will be once the shock is reabsorbed. Agents understand that eventually output and inflation will experience a large discrete jump, but they do not know when. This creates uncertainty. If instead the Fiscally led regime is expected to follow the zero lower bound, agents expect that all future fiscal imbalances will now affect the macroeconomy. Therefore, even if policymakers succeed in bringing the economy closer to where it will be once out of the recession, short run uncertainty is still high.

While short run uncertainty is high in both cases, the behavior of long run uncertainty varies significantly depending on what exit strategy is announced or expected. When the Monetary led regime is announced, long run uncertainty is low because agents know that by then the economy will be out of the zero lower bound and policymakers' behavior will lead to a stable macroeconomic environment. Instead, when the Fiscally led regime is announced, agents anticipate that macroeconomic volatility will be high in the future as a result of policymakers' behavior. This is reflected in the dynamics of uncertainty once the economy exits the zero lower bound. If policymakers return to the Monetary led regime, uncertainty goes immediately back to the pre-crisis levels at all horizons; however if the Fiscally led regime prevails, uncertainty remains high.

One might correctly point out that when a departure from the Monetary led policy mix is announced, the high persistence of the Fiscally led policy mix is critical for long-run macroeconomic uncertainty to rise during the crisis. It is then worth emphasizing that the announcement is effective in mitigating the recession if and only if it is able to convince agents that the Fiscally led policy mix will prevail for a long time. Only under these circumstances agents expect that debt will be inflated away. If the Fiscally led regime had low persistence, the announcement would lead to effects on the output gap, inflation, and the macroeconomic volatility that are very similar to those associated with announcing a return to the Monetary led policy mix. Agents would simply expect a change in the timing of the fiscal adjustments. Therefore, the increase in uncertainty and the reduction in the magnitude of the recession are two sides of the same coin.

Finally, when policymakers do not make any announcement, uncertainty is high at every horizon. This reflects two sources of uncertainty: Future shocks and policymakers' future behavior. The second source of uncertainty is particularly relevant in this case and it is what drives the sharp increase of uncertainty at every horizons when the economy is at the zero lower bound. The result is that inflation is on target but surrounded by large uncertainty, as illustrated in the second panel of the top panels of Figure 5.

It might be argued that many countries, including the US, are now in a situation with large uncertainty about the way policymakers will deal with the extremely large stock of debt that has been accumulated during the recent crisis. Part of the debt is expected to be absorbed by higher growth once the economy is out of the crisis. However, it is quite likely that this factor alone will not be enough to correct the dynamics of the US sovereign debt in absence of substantial fiscal adjustments. The results presented here highlight how policy uncertainty can lead to a situation in which inflation remains close to the target even if the economy spends a significant amount of time at the zero lower bound. At the same time, the model predicts that policy uncertainty leads to macroeconomic uncertainty.

Our results can also explain why markets swing between the fear of inflation and the fear of deflation in response to policymakers' announcements or decisions, as pointed out by Kitsul and Wright (2013). It is not hard to imagine that any announcement moves the relative weights assigned to the two opposite exit strategies outlined above. Finally, the model is able to replicate a situation in which long-run inflation expectations are low on average, but surrounded by rising uncertainty. Specifically, as shown in Figure 5, even if policymakers announce that after the zero-lower-bound period they will return to the Monetary led regime, the large increase in the stock of debt and the possibility of policymakers revising their decision determine a slow moving increase in inflation and an increase in uncertainty.

5.2.2 Contradictory announcements

We will now show that a lack of coordination between the monetary and fiscal authorities can lead to disastrous outcomes, with losses both in the short and long run. These outcomes are more likely to occur if the signals that policymakers send to the public become contradictory, something that is not far from happening in the current economic and political climate. In fact, since the beginning of the crisis the Federal Reserve has repeatedly stated that the exceptional measures taken during the current crisis should not be interpreted as evidence of a lack of commitment to low and stable inflation in the future. At the same time, the explosive projections for the debt-to-GDP ratio that are routinely presented by the fiscal authority suggests that future increases in taxes will not be large enough to balance the fiscal budget. These two "signals" are contradictory because the Federal Reserve cannot control inflation if the fiscal authority is not committed to levy taxes in order to stabilize debt. This lack of coordination could induce agents to think that a conflict between the two authorities will eventually arise. In other words, agents could think that once the economy has made its way through the crisis a period during which both policies are active could follow.

When considered in isolation, a regime in which both authorities are active implies no stable solution (Leeper 1991). To see why, suppose that inflation is above target and that the Federal Reserve tries to push it down by increasing the federal funds rate more than one-to-one in response to the observed deviation. This action prompts an increase in the real interest rate, a contraction in output and consequently an acceleration in rise of the debt-to-GDP ratio. This acceleration in the dynamic of the debt-to-GDP ratio would require an increase in taxation, but agents know that this is not going to happen because the fiscal authority is active. Therefore, the adjustment has to come through an increase in inflation that triggers an even larger increase in the FFR and so on. Clearly, the economy is on an explosive path, and no *stationary* solution exists.

However, things are different when agents are aware of regime changes. In this case, the consequences of a conflict between the two authorities are determined by agents' beliefs about the way the conflict will be resolved. We modify the model to have a total of five possibilities for policymakers' behavior at the zero lower bound. As in the previous case, policymakers can decide to make coordinated announcements. In this case, two options are available for the exit strategy: return to fiscal discipline or prolonged deviation from the Monetary led policy mix. Alternatively, policymakers can release statements that are contradictory and that induce agents to think that a prolonged *fight* between the two authorities will follow the crisis. In this case, we consider two scenarios. In the first one, agents believe that the monetary authority will eventually prevail and that the fiscal authority will passively accommodate its behavior. In the second scenario, agents are convinced that the fiscal authority will prevail. To implement the

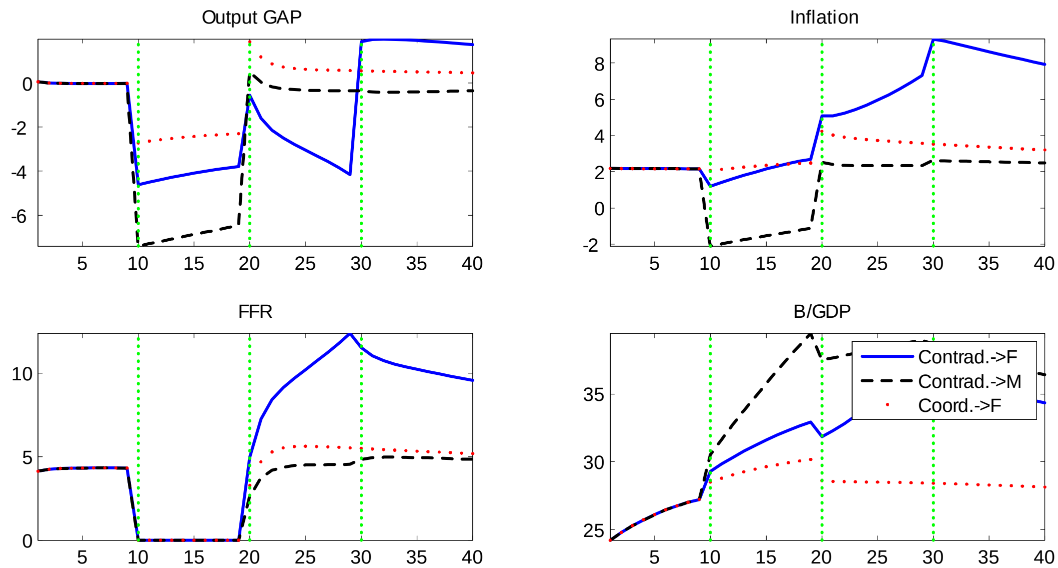

Figure 6: **Macroeconomic Dynamics with Contradictory Announcements:** Behavior of an economy that enters the zero lower bound with an above-steady-state amount of debt. Three cases are considered: (1) and (2) contradictory announcements that induce agents to anticipate a fight between the two authorities; (3) policymakers make coordinated announcements that the Monetary led regime will be abandoned (Coord.->F). In the first scenario (Contrad. ->M), agents anticipate that the monetary authority will prevail; in the second scenario (Contrad.->F), agents anticipate that the fiscal authority will prevail. In the simulations, the conflict between the two authorities last ten quarters. The first two vertical green dotted lines indicate the period in which the economy is at the zero lower bound. The second and third vertical green dotted lines indicate the duration of the *fight regime*.

idea that a conflict between the two authorities will follow, we assume that agents anticipate that after the zero-lower-bound period the economy will enter a *fight regime* in which both monetary and fiscal policies are active. The persistence of the fight regime is set to 0.86 and in the simulations it is assumed to last ten quarters. Finally, policymakers can decide to do nothing and leave agents uncertain about which exit strategy will be followed.

Figure 6 reports the evolution of the variables of interest in an economy that is hit by the large negative preference shock ($\xi_t^d = l$) at time 10 and is assumed to switch back to the high preference shock at time 20. From time 20 through time 30, policymakers are in the *fight regime*. For the sake of clarity, we report results for three of the five possible scenarios. The case in which policymakers explicitly announce that fiscal discipline will be abandoned (red dotted line) represents the benchmark case. The dynamics are very similar to the ones described for the analogous case in Subsection 5.2.1, implying that the impact of the alternative scenarios on agents' expectations are negligible. However, it is worth pointing out that once again we observe a situation in which inflation is on target and the economy is still in a recession.

The second and third cases are the most interesting, especially when compared with this benchmark scenario. We shall start with the case in which agents expect that after the fight regime the monetary authority will prevail (black dashed line). Notice that even if the fiscal authority has announced, implicitly or explicitly, that fiscal adjustments will not be implemented once the economy is out of the zero lower bound, the economy is still in a deep recession. In fact, the behavior of the economy is virtually identical to the one that would be observed if policymakers were announcing that after the economy exits the zero lower bound a policy of fiscal austerity would be implemented.[8] To understand why, notice that once the economy is out of the zero lower bound, during the period characterized by a fight between the two authorities, debt keeps accumulating because the fiscal authority is not adjusting taxes to stabilize debt. However, there are no effects on output and inflation as agents understand that eventually taxes will be raised and debt will be repaid. The attempts of the fiscal authority are simply not effective at stimulating the economy out of the recession because agents are convinced that debt will eventually be repaid.

The solid blue line reflects the case in which agents expect that the fiscal authority will eventually prevail in a fight between the monetary and fiscal authorities. Therefore, if the fiscal authority announces that fiscal discipline will be abandoned, while the monetary authority insists that it will keep seeking a low and stable target for inflation, agents anticipate a conflict between the two authorities followed by the Fiscally led regime. At the zero lower bound, policymakers are not able to avoid a deep recession, even if agents understand that in the very long run debt will be inflated away. To understand why, we have to focus on what happens once the economy exits the zero lower bound. Agents expect that eventually debt will be inflated away, so inflation starts increasing during the period characterized by the conflict between the two authorities. The monetary authority tries to push inflation down, causing a recession. The recession and the high real interest lead to an increase in the debt-to-GDP ratio. Since the fiscal authority does not make the necessary fiscal adjustments and agents expect that eventually the monetary authority will give up stabilizing inflation, the additional stock of debt immediately generates inflationary pressure. Therefore, the increase in real interest rates has the perverse effect of generating even more inflation. This creates a *vicious circle* that causes inflation and the nominal interest rate to drift up, while at the same time the recession becomes deeper and deeper. Finally, when the fight between the two authorities is resolved, the monetary authority gives up and accommodates a jump in inflation. The real interest rate falls deeply, inducing an increase in real economic activity. Agents anticipate this chain of events coming, and their anticipation has an immediate negative impact on the level of real economic activity at the zero lower bound.

Uncertainty also behaves in a very different way across the two cases. When agents expect that the monetary authority will eventually prevail (upper panels of Figure 7), short-run output uncertainty is high at the zero lower bound. However, long-run uncertainty is low because agents

[8] We do not report this case here, but it is very similar to the equivalent scenario captured by the dotted line of Figure 4.

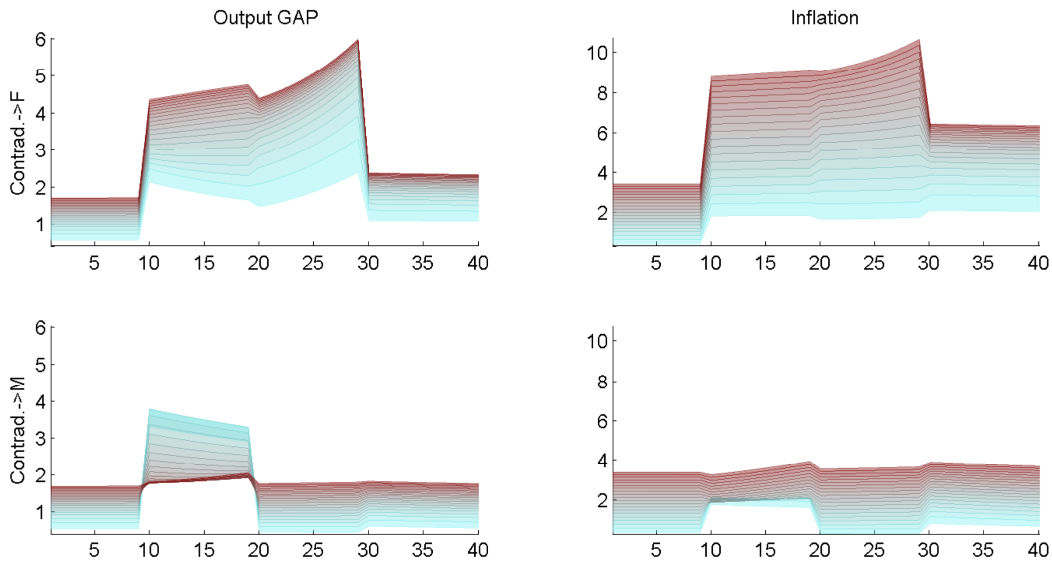

Figure 7: **Evolution of Uncertainty with Contradictory Announcements:** Evolution of uncertainty for an economy that enters the zero lower bound with an above-steady-state amount of debt. Two cases are considered. In both of them contradictory announcements induce agents to anticipate a fight between the two authorities. In the first scenario (Contrad.->M), agents anticipate that the monetary authority will prevail; in the second scenario (Contrad.->F), agents anticipate that the fiscal authority will prevail. In the simulations, the conflict between the two authorities last ten quarters. The zero-lower-bound period lasts from period $t = 11$ through period $t = 20$. The fight regime lasts from period $t = 21$ through period $t = 30$.

expect that, despite the possibility of a conflict between the two authorities, the central bank will eventually prevail, leading to a stable macroeconomic environment. For the same reason, long-run uncertainty remains low also during the ten quarters characterized by the conflict between the two authorities. Instead, when agents anticipate that the fiscal authority will eventually prevail and debt will be inflated away, short-run uncertainty at the zero lower bound is relatively low for both inflation and output. However, uncertainty at medium/long horizons is very high and keeps increasing over time. This is because agents anticipate a turbulent period during which the conflict between the two authorities will cause high inflation and a prolonged recession. This period will eventually be followed by a large swing in both inflation and real economic activity as illustrated in Figure 6 . The more time is spent at the zero lower bound, the larger the stock of debt that will have to be inflated away, the larger the effects of the conflict between the two authorities on uncertainty.

In summary, the case in which contradictory announcements are resolved with the abandonment of fiscal discipline leads to a double loss. First, inflation stability is eventually abandoned, but this does not bring any benefit for the economy while at the zero lower bound. Second, the conflict that follows the zero-lower-bound period prompts large output losses combined with high inflation because of the inflationary spiral. Therefore, policymakers should be very cautious in the way that they communicate with the public, especially if their statements could induce agents to believe that a conflict between the monetary and fiscal authorities will arise. Furthermore, even if this worst-case scenario does not materialize, the lack of coordination can completely jeopardize policymakers' ability to stimulate economic activity.

6 Escaping the Great Recession

We showed that an exceptionally large contraction in demand leads to a deep recession that pushes the nominal interest rate to the zero lower bound. When this happens, policymakers would like to generate an increase in inflation expectations to stimulate the economy in the short run. Policymakers can achieve that by embracing the Fiscally led regime. However, in order for such a regime change to have an effect, agents have to perceive it as long lasting. In fact, announcing that a Fiscally led policy mix will be implemented after the economy has exited the zero lower bound would lead to virtually the same macroeconomic effects as announcing fiscal discipline if the announced regime were expected to *last for too short a time*. In other words, once out of the recession, policymakers have to follow the Fiscally led policy mix for a *prolonged* period of time. Since such a prolonged deviation from fiscal discipline leads to a persistent increase in uncertainty at all horizons, policymakers can be rightfully reluctant to abandon the Monetary led regime because this regime guarantees a stable macroeconomic environment during regular times.

In this section, we propose a possible resolution of this policy trade-off. Policymakers can achieve the goal of increasing inflation expectations and at the same preserving long-run macroeconomic stability by committing to inflate away *only* the amount of debt resulting from the large preference shock itself. At same time, policymakers would commit to fully repay the pre-existing amount of debt and to follow the Monetary led rule in response to all other *business cycle shocks* ($\epsilon_{z,t}$, $\epsilon_{x,t}$, and $\epsilon_{R,t}$). This commitment determines a sort of *automatic stabilizer.* The large preference shock can potentially cause a deep recession and a corresponding large increase in debt. The expectation that this extra amount of debt is going to be inflated away determines an increase in inflation expectations and a corresponding drop in the real interest rate. This stimulates real economic activity, reducing the size of the output contraction. This mechanism can be strong enough to prevent the economy from hitting the zero lower bound. At the same time, agents understand that the increase in inflation is the result of a well-defined, exceptional contractionary event, which policymakers are not responsible for, while policy strategies to cope with business cycle disturbances are unchanged. Therefore, the level of uncertainty once out of the recession immediately returns to the pre-crisis levels.

To illustrate these points, we modify the model and assume that policymakers behave according to the Monetary led policy mix all the time, except when responding to the discrete preference shock d_t. Specifically, we assume that the response of the nominal interest rate to

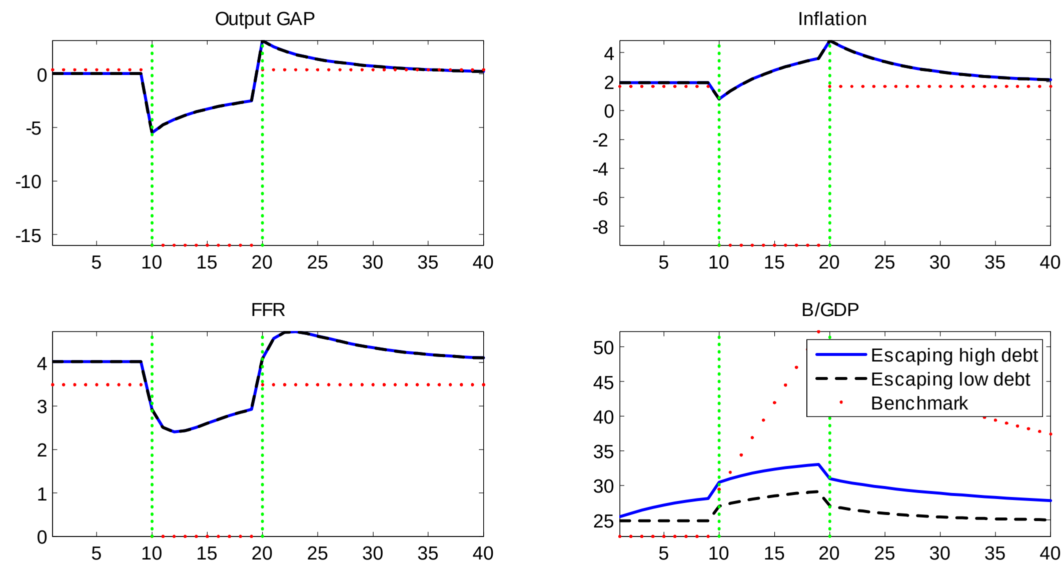

Figure 8: **Macroeconomic Dynamics while Escaping the Great Recession**: Response to a large contraction in aggregate demand. The solid blue line and black dashed assume that policymakers inflate away all the debt deriving from the large preference shock, while they are committed to repay all pre-existing debt. In the first case (Escaping high debt), debt is above its steady-state level; in the second case, (Escaping low debt), debt is initially at the steady state ("Escaping low debt"). Following this strategy allows policymakers to avoid the zero lower bound. The red dotted line corresponds to the benchmark case in which the monetary led regime is always in place and the zero lower bound is binding. The vertical green dotted lines indicate the period in which the economy is at the zero lower bound.

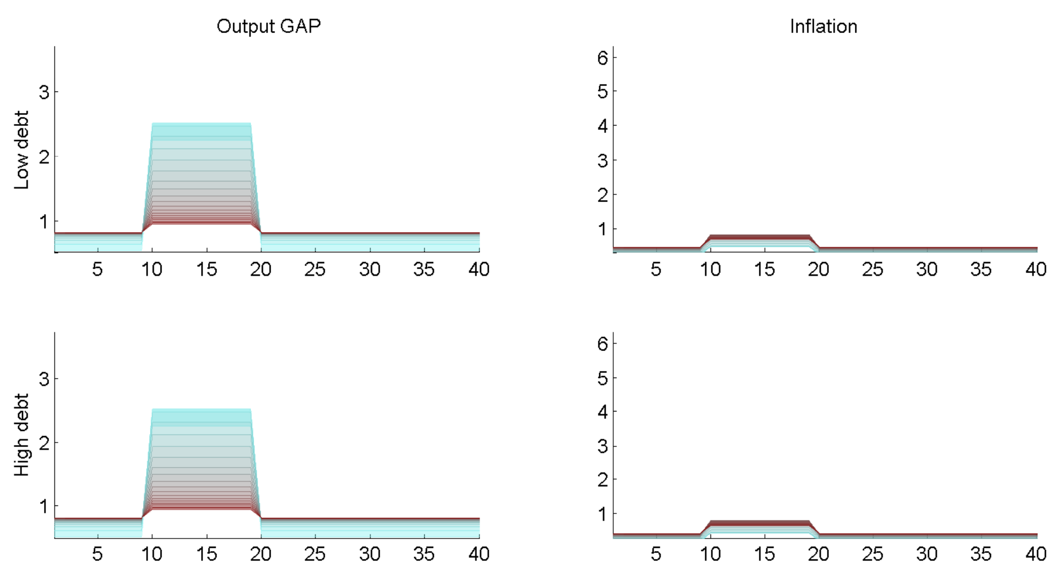

Figure 9: **Evolution of Uncertainty while Escaping the Great Recession**: Evolution of uncertainty in response to a large contraction in aggregate demand when policymakers systematically inflate away all the debt deriving from the large preference shock, while they are committed to repay all pre-existing debt. In the first case ("Low debt"), debt is initially at the steady state; in the second case ("High debt"), debt is above steady state. The zero-lower-bound period lasts from period $t = 11$ through period $t = 20$.

inflation and of primary surpluses to debt are both zero *if* movements in these variables result from the preference shock. In response to all the other fluctuations, policymakers instead follow the Monetary led policy mix. In order to implement this policy we construct a *shadow economy* to keep track of the amount of debt deriving from the discrete preference shock. Policymakers do not react to debt and inflation caused by the discrete preference shock, while they follow the Monetary led policy mix in response to all other shocks. If we denote debt and inflation of the shadow economy in which discrete preference shocks are shut down as b_t^{nd} and π_t^{nd}, we can write the linearized policy rules as:

$$\begin{aligned} \widetilde{s}_t &= \delta_b^M \widetilde{b}_{t-1}^{nd} + \delta_b^E \left(\widetilde{b}_{t-1} - \widetilde{b}_{t-1}^{nd} \right) + \dots \quad , \\ \widetilde{R}_t &= (1-\rho_R) \left(\psi_\pi^M \widetilde{\pi}_t^{nd} + \psi_\pi^E \left(\widetilde{\pi}_t - \widetilde{\pi}_t^{nd} \right) \right) + \dots \quad , \end{aligned}$$

where we assume $\delta_b^E = \psi_b^E = 0$.[9] This implies that future fiscal adjustments are not enough to stabilize the entire stock of debt $\widetilde{b}_{t-1}$, but only $\widetilde{b}_{t-1}^{nd}$: The amount $\widetilde{b}_{t-1} - \widetilde{b}_{t-1}^{nd}$ is going to be inflated away. At the same time, the central bank accommodates the resulting increase in inflation $\widetilde{\pi}_t - \widetilde{\pi}_t^{nd}$. This is the increase of inflation necessary in order to inflate away the additional amount of debt resulting from the recession induced by the negative preference shock.

In Figure 8, we consider two scenarios. In the first one (solid blue line), when the negative preference shock hits, debt is above its steady state level. In the second case (black dashed line), debt is instead assumed to be at the steady state. For comparison, we report the benchmark new-Keynesian model of Subsection 5.1 in which policymakers follow the Monetary led policy mix all the time. The drop in real economic activity is substantially smaller than the drop observed in the benchmark model, and we do not observe deflation in the two scenarios. This is due to the mechanism outlined earlier: The increase in expected inflation prevents a large drop in inflation today and determines a decline in the path of the real interest rate. Notice that the resulting increase in inflation after the economy exits the zero lower bound is relatively modest. This is because the recession is largely mitigated, implying that the amount of debt that needs to be inflated away turns out to be small. Finally, it is important to point out that the behavior of the macroeconomy does not depend on the level of debt prevailing when the economy entered the zero lower bound because the preexisting amount of debt is always backed by future fiscal adjustments.

The fact that policymakers inflate away only an amount of debt that can be imputed to the large negative preference shock has important consequences for the level of uncertainty and macroeconomic volatility faced by agents in the model. Figure 9 shows that as soon as the shock is absorbed, uncertainty returns to the lower levels prevailing before the recession because

[9] Appendix A.3 explains more thoroughly how we model the shock-specific policy rule.

policymakers have never changed their behavior with respect to other disturbances. Business cycle shocks are always stabilized according to the Monetary led policy mix. The result is that the overall level of uncertainty is much lower than in the benchmark case both in and out of the zero lower bound. Policymakers do not have to trade off short-run gains with long-run losses anymore.

Furthermore, given that policymakers always follow the Monetary led policy mix with respect to all business cycle disturbances, we observe a substantial reduction in inflation volatility with respect to the case in which switches to the Fiscally led policy mix are possible at each point in time. Under the proposed policy, agents know that policymakers would generate a spur of inflation only in response to a large negative preference shock. Notice that this *reduces* uncertainty because it prevents the possibility of large deflationary spirals. In this respect, it is interesting to notice that the resulting equilibrium path for inflation is in line with the well-established prescriptions of Eggertsson and Woodford (2003) for coping with zero-lower-bound episodes: policymakers should foster a smooth increase of inflation during and after the zero-lower-bound period. However, the mechanism outlined in this paper is quite different.

An important question is how the policy presented here could be implemented in practice. As is common in the literature, we assume in this paper that agents have perfect information and can observe the shocks hitting the economy. In reality, policymakers and agents might not have the possibility of exactly disentangling the contribution of the different shocks to the evolution of the macroeconomy. In that case, a simpler policy would consist of announcing a target for the debt-to-GDP ratio based on the pre-crisis level of debt. Policymakers would commit to raise enough taxes in order to repay the pre-existing level of debt or a projection of this value, but they would not respond to *any* movement in the debt-to-GDP ratio that occurs during the crisis. The part of debt above the announced target would then be inflated away. Policymakers would then return to the Monetary led regime once the crisis is over. This approach implies that *any* business cycle shock that occurs during the crisis would also change the level of debt that is going to be inflated away, while in the policy presented in this paper only the amount of debt deriving from the discrete preference shock would be inflated away. As a result this more realistic approach is associated with a slightly higher uncertainty during the crisis than the shock-specific strategy we outlined, but it would have the important advantage of being easy to communicate.

Finally, in our model, the shock-specific policy occurs in response to a large negative preference shock. In reality there might be many disturbances that could require a similar change in policy. Furthermore, there might be disagreement among policymakers about whether a realized shock is large enough to trigger the policy change. A simple criterion would consist of following this alternative policy in response to all those disturbances that would drive the nominal interest rate to negative territory under the Monetary led policy mix.

Our results are related to the idea that one can rule out liquidity traps by making them fiscally unsustainable, as first proposed by Woodford (2003) and explored in a perfect foresight setting by Benhabib, Schmitt-Grohe, and Uribe (2002). An important difference is that we study the relation between policy uncertainty, inflation dynamics, and macroeconomic uncertainty at the zero lower bound. A central result of our paper consists of highlighting the trade-off between avoiding deflation and preserving long run macroeconomic stability that seems to characterize the current policy debate. A fiscally led policy mix would allow policymakers to escape the Great Recession, but it would give rise to high macroeconomic uncertainty once the economy is out of the zero lower bound. We have been able to show this important result by studying the macroeconomic dynamics at the zero lower bound within a stochastic framework and allowing for policy uncertainty. Our shock specific rule is able to resolve this policy trade-off without abandoning the appeal of simple rules.

In summary, the approach proposed in this section succeeds in mitigating the recession, and at the same time in preserving long-run macroeconomic stability. The proposed policy succeeds in mitigating deep recessions because it modifies agents' beliefs about policymakers' *long-run* behavior in response to a specific shock. In fact, policymakers are committing to *never* increase taxes in response to the amount of debt accumulated during these deep recessions and at the same time not to fight the resulting increase in inflation. This policy triggers an increase in *short-run* inflation expectations and an immediate increase in inflation as large preference shocks hit the economy. At the same time, the proposed policy preserves long-run macroeconomic stability because policymakers are still committed to fully repay any preexisting stock of debt and to fully neutralize all other present and future disturbances affecting the debt-to-GDP ratio.

7 Conclusions

Deflation and a large recession do not necessarily arise when the economy enters the zero lower bound. If agents are uncertain about the way policymakers will deal with a rising stock of debt, inflation remains around its target value and the output loss is substantially mitigated. In this situation, any announcement about policymakers' future behavior can generate large swings in expectations and in the state of the economy. Therefore, at the zero lower bound, a well-defined exit strategy can be very powerful. Policymakers can avoid a large collapse in output announcing a prolonged deviation from the Monetary led regime. Such an announcement is effective as long as the deviation is perceived to last for *sufficiently long* after the zero-lower-bound period. Policymakers might be rightfully reluctant to follow this strategy because it leads to an unstable macroeconomic environment once the economy is out of the zero lower bound.

However, the policy trade-off can be resolved announcing that only the portion of debt deriving from the exceptionally large shock will be inflated away. This creates a sort of automatic stabilizer: When the negative preference shock hits, agents foresee an increase in spending that in turn translates into an increase in inflation. Inflation starts increasing immediately through the expectation channel. The decline in real interest rates largely mitigates the recession and, consequently, the increase in debt itself. The final outcome is an equilibrium in which a *moderate* increase in inflation is spread over several quarters. Importantly, macroeconomic volatility returns to the pre-crisis levels as soon as the shock is absorbed because policymakers never changed their behavior with respect to the other disturbances affecting the macroeconomy. Therefore, policymakers succeed in mitigating the recession and preserving a stable macroeconomic environment.

In his seminal contribution Bloom (2009) points out that uncertainty can be detrimental for real economic activity. This channel is absent here and would require moving to higher-order approximations, as in Fernandez-Villaverde, Kuester, Guerron-Quintana, and Rubio-Ramirez (2011) and Johannsen (2013). These papers study the role of fiscal uncertainty in slowing down the recovery during the current crisis, but they assume that government debt is always backed by future fiscal surpluses while agents face uncertainty regarding the magnitude of the innovations to the fiscal instruments. In our model, agents instead are uncertain about the *rules* governing policymakers' behavior. An interesting extension for future research would consist of integrating the two approaches, especially considering that our model predicts that high uncertainty is an inherent implication of the economy entering the zero lower bound.

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A Technical details

A.1 Linearization

The Markov-switching process for d_t represents a non-Gaussian shock. In order to log-linearize the model, we follow these steps (see Schorfheide 2005; Liu, Waggoner, and Zha 2011; and Bianchi and Ilut 2012 for more details):

1. Compute the ergodic mean $\overline{d}$ for the preference shock d_t.

2. Verify that the zero lower bound is not binding at $\overline{d}$.

3. Define the regimes in terms of policymakers' behavior and the value for the preference shock: $\xi_t \equiv \left(\xi_t^d, \xi_t^p\right)$.

4. Conditional on each regime, linearize/log-linearize all equations around the deterministic steady state and define deviations of the preference shock from its ergodic mean as $\widetilde{d}_t = d_t - \overline{d}$ and $\widetilde{\overline{d}}_{\xi_t^d} = \overline{d}_{\xi_t^d} - \overline{d}$. Notice that $\widetilde{d}_t$ can assume only two values $\widetilde{\overline{d}}_h$ and $\widetilde{\overline{d}}_l$ and that the non-linearity associated to a regime change is retained.

5. Use the methods developed by Farmer, Waggoner, and Zha (2009) to solve the model. The solution algorithm returns a MS-VAR whose parameters depend on the probability of moving across regimes H, the structural parameters θ, and the current state ξ_t:

$$Z_t = c\left(\xi_t, H, \theta\right) + T\left(\xi_t, H, \theta\right) Z_{t-1} + R\left(\xi_t, H, \theta\right) Q\varepsilon_t$$

   where Q is a diagonal matrix that contains the standard deviations of the structural shocks and Z_t is a vector with all variables of the model.

Unlike other papers that have used the technique described here, our model allows for non-orthogonality between policymakers' behavior and a discrete shock. This allows us to solve a model in which agents take into account that a large preference shock leads to an immediate change in policy, the zero lower bound, and, potentially, to further changes. This proposed method is general and can be applied to other cases in which a shock induces a change in the structural parameters.

A.2 Matrices used in the simulations

We here describe the matrices used in the simulations reported in the paper.

A.2.1 No zero lower bound

policymakers' behavior evolves according to the transition matrix:

$$H^p = \begin{bmatrix} .99 & .01 \\ .01 & .99 \end{bmatrix},$$

and $d_t = \overline{d}$ for each t.

A.2.2 Benchmark New-Keynesian model

In the benchmark New-Keynesian model, policymakers always follow the Monetary led regime when out of the zero lower bound. Furthermore, there is only one zero lower bound regime from which agents expect to return to the Monetary led regime:

$$H^i = H^z = H^o = H^p = \begin{bmatrix} 1 & 0 \\ 0 & 0 \end{bmatrix}, \; H^d = \begin{bmatrix} p_{hh} & 1 - p_{ll} \\ 1 - p_{hh} & p_{ll} \end{bmatrix}.$$

A.2.3 Coordinated announcements

At the zero lower bound, we distinguish three cases, based on the exit strategy:

1. Policy uncertainty is present (no announcement is made).
2. Policymakers announce that they will move to the Monetary led regime once the economy out of the zero lower bound.
3. Policymakers announce that they will move to the Fiscally led regime once the economy is out of the zero lower bound.

We assume that the three cases are equally likely and their probabilities do not depend on the regime that was in place when the negative preference shock hits. We then have:

$$H^p = \begin{bmatrix} .99 & .01 \\ .01 & .99 \end{bmatrix}, \; H^o = \begin{bmatrix} .5 & 1 & 0 \\ .5 & 0 & 1 \end{bmatrix},$$

$$H^i = \begin{bmatrix} .33 & .33 \\ .33 & .33 \\ .33 & .33 \end{bmatrix}, \; H^z = \begin{bmatrix} .99 & .005 & .005 \\ .005 & .99 & .005 \\ .005 & .005 & .99 \end{bmatrix},$$

$$H^d = \begin{bmatrix} .98 & .20 \\ .02 & .80 \end{bmatrix}.$$

A.2.4 Contradictory announcements

At zero lower bound, we distinguish three cases, based on the exit strategy:

1. Policy uncertainty (no announcement is made).
2. Policymakers announce that they will move to the Monetary led regime once the economy is out of the zero lower bound.
3. Policymakers announce that they will move to the Fiscally led regime once the economy is out of the zero lower bound.
4. Contradictory announcements leading to a conflict between monetary and fiscal authorities will be resolved in favor of the monetary authority.
5. Contradictory announcements leading to a conflict between monetary and fiscal authorities will be resolved in favor of the fiscal authority.

We assume that the five cases are equally likely and their probabilities do not depend on the regime that was in place when the negative preference shock hits. We then have:

$$H^p = \begin{bmatrix} .99 & .01 & .14 & \\ .01 & .99 & & .14 \\ & & .86 & \\ & & & .86 \end{bmatrix}, \ H^o = \begin{bmatrix} .25 & 1 & & & \\ .25 & & 1 & & \\ .25 & & & 1 & \\ .25 & & & & 1 \end{bmatrix},$$

$$H^i = \begin{bmatrix} .20 & .20 \\ .20 & .20 \\ .20 & .20 \\ .20 & .20 \\ .20 & .20 \end{bmatrix}, \ H^z = \begin{bmatrix} .98 & .005 & .005 & .005 & .005 \\ .005 & .98 & .005 & .005 & .005 \\ .005 & .005 & .98 & .005 & .005 \\ .005 & .005 & .005 & .98 & .005 \\ .005 & .005 & .005 & .005 & .98 \end{bmatrix},$$

$$H^d = \begin{bmatrix} .98 & .20 \\ .02 & .80 \end{bmatrix},$$

where the third and fourth out-of-the-zero-lower-bound regimes are both characterized by both monetary and fiscal authorities to be active and only differ in terms of the authority that will eventually prevail.

A.3 Shock-Specific Policy Rules

In this appendix, we detail the DSGE model used to perform the analysis of Section 6, in which policymakers do not respond to movements in debt deriving from the discrete preference shocks

ξ_t^d. This DSGE model can be expressed as follows:

THE ACTUAL ECONOMY:

$$\widetilde{\pi}_t = \beta E_t(\widetilde{\pi}_{t+1}) + \kappa(\widetilde{y}_t - z_t), \tag{16}$$

$$\widetilde{y}_t = E_t\left(\widetilde{y}_{t+1}\right) - \left(\widetilde{R}_t - E_t\left(\widetilde{y}_{t+1}\right)\right) + \widetilde{d}_t - \mathbf{E}_t\left(\widetilde{d}_{t+1}\right), \tag{17}$$

$$\widetilde{b}_t = \beta^{-1}\widetilde{b}_{t-1} + b\beta^{-1}\left(\widetilde{R}_{t-1} - \widetilde{\pi}_t - \Delta\widetilde{y}_t\right) - \widetilde{s}_t, \tag{18}$$

$$\widetilde{s}_t = \delta_b^M b_{t-1}^{nd} + \delta_b^E\left(b_{t-1} - b_{t-1}^{nd}\right) + \delta_y\left(\widetilde{y}_t - z_t\right) + x_t, \tag{19}$$

$$\widetilde{R}_t = \rho_R\widetilde{R}_{t-1} + (1-\rho_R)\left(\psi_\pi^M\pi_t^{nd} + \psi_\pi^E\left(\pi_t - \pi_t^{nd}\right) + \psi_y\left[\widetilde{y}_t - z_t\right]\right) + \sigma_R\epsilon_{R,t}. \tag{20}$$

THE SHADOW ECONOMY

$$\widetilde{\pi}_t^{nd} = \beta E_t(\widetilde{\pi}_{t+1}^{nd}) + \kappa(\widetilde{y}_t^{nd} - z_t), \tag{21}$$

$$\widetilde{y}_t^{nd} = E_t\left(\widetilde{y}_{t+1}^{nd}\right) - \left(\widetilde{R}_t^{nd} - E_t\left(\widetilde{y}_{t+1}^{nd}\right)\right), \tag{22}$$

$$\widetilde{b}_t^{nd} = \beta^{-1}\widetilde{b}_{t-1}^{nd} + b\beta^{-1}\left(\widetilde{R}_{t-1}^{nd} - \widetilde{\pi}_t^{nd} - \Delta\widetilde{y}_t^{nd}\right) - \widetilde{s}_t^{nd}, \tag{23}$$

$$\widetilde{s}_t^{nd} = \delta_b^{nd}\widetilde{b}_{t-1}^{nd} + \delta_y\left(\widetilde{y}_t^{nd} - z_t\right) + x_t, \tag{24}$$

$$\widetilde{R}_t^{nd} = \rho_R\widetilde{R}_{t-1}^{nd} + (1-\rho_R)\left(\psi_\pi^{nd}\widetilde{\pi}_t^{nd} + \psi_y\left[\widetilde{y}_t^{nd} - z_t\right]\right) + \sigma_R\epsilon_{R,t}. \tag{25}$$

EXOGENOUS PROCESSES

$$\widetilde{d}_t = \widetilde{\overline{d}}_{\xi_t^d}, \tag{26}$$

$$z_t = \rho_z z_{t-1} + \sigma_z\epsilon_{z,t}, \tag{27}$$

$$x_t = \rho_x x_{t-1} + \sigma_x\epsilon_{x,t}. \tag{28}$$

It should be noted that the equations governing the behavior of the shadow economy (21)-(25) differ from those of the actual economy (16)-(20) in only one dimension: While the actual economy is buffeted by all types of shocks (i.e., ξ_t^d, $\epsilon_{r,t}$, $\epsilon_{z,t}$, and $\epsilon_{x,t}$), the shadow economy is not hit by the discrete preference shock ξ_t^d. The equations of the shadow economy work as a device to keep track of the changes in the policy targets (i.e., the stock of debt b_{t-1}^{nd} and the rate of inflation π_t^{nd}) in equations (19) and (20). Finally, it is important to point out that equations (16)-(28) constitute a system of linear rational expectations equations with fixed coefficients that can be easily solved using one of the many solvers available (e.g., *Gensys* by Sims, 2002).

B Additional Results

This section reports all impulse responses for the model of Section 4 in which zero lower bound episodes are ruled out.

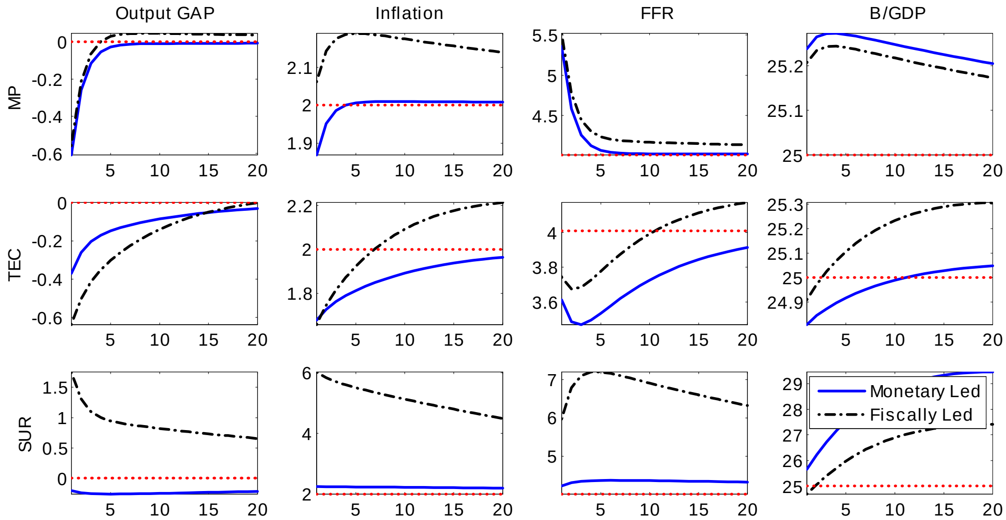

Figure 10: Impulse responses for the benchmark model in which the policy mix is allowed to change over time and agents take this into account while forming expectations.

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