



Federal Reserve Bank of Chicago

Escaping the Great Recession

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Abstract

We show that policy uncertainty about how the rising public debt will be stabilized accounts for the lack of deflation in the US economy at the zero lower bound. We first estimate a Markov-switching VAR to highlight that a zero-lower-bound regime captures most of the comovements during the Great Recession: a deep recession, no deflation, and large fiscal imbalances. We then show that a micro-founded model that features policy uncertainty accounts for these stylized facts. Finally, we highlight that policy uncertainty arises at the zero lower bound because of a trade-off between mitigating the recession and preserving long-run macroeconomic stability.

JEL Codes: E31, E52, E62, E63, D83

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1 Introduction

The recent financial crisis and the deep recession that followed have led to a substantial change in the conduct of monetary policy, with interest rates stuck at the zero lower bound for the past eight years. A key prediction of the New Keynesian paradigm is that, in this situation, we should have observed deflation. However, this prediction has not materialized. Following Hall's Presidential Address to the American Economic Association, some researchers have labeled this observation "Hall's puzzle" (Hall 2011). Simultaneously, the crisis has triggered a vibrant debate about the best way to deal with the zero lower bound. Two polar views have emerged. The first one advocates a robust fiscal stimulus sometimes even accompanied by a reduced emphasis on inflation stabilization (Romer 2009, Sims 2010a). The second one strongly opposes the idea of abandoning policies that worked in the past (Plosser 2012). This debate has occurred against a background of acute fiscal strain. In 2009, the US deficit-to-GDP ratio was the highest since the Korean war. Furthermore, by 2012 the debt-to-GDP ratio had reached levels unprecedented since the end of World War II and, based on the Congressional Budget Office projections, is expected to continue increasing for the foreseeable future (CBO 2016). It is conceivable that this debate and the severe fiscal imbalance have led to a rise in uncertainty about how debt will be stabilized. In this paper, we show that policy uncertainty can account for the absence of deflation that characterized the Great Recession.

We first establish a series of stylized facts by fitting a Markov-switching VAR to post-World War II data. We include inflation, GDP growth, the federal funds rate, and the deficit-to-debt ratio. The model identifies three distinct regimes. The movements between the first two regimes capture a low frequency relation between the deficit-to-debt ratio and inflation. During the 1960s and 1970s, when Regime 1 is in place, real interest rates are low, the deficit-to-debt ratio trends up, and so does inflation. These dynamics revert once the economy moves to Regime 2 in the early 1980s: Real interest rates increase, inflation falls, and so does the deficit-to-debt ratio. Instead, the third regime captures the bulk of the dynamics during the Great Recession: a large contraction in real activity, a short lasting drop in inflation, a jump in primary deficits, and

the zero lower bound. During this zero-lower-bound regime, fiscal shocks have large effects on inflation, providing evidence that fiscal imbalances play a role in explaining inflation dynamics during the Great Recession.

These findings suggest that the following are desirable properties of a structural model whose objective is to study the Great Recession. First, the model should feature three policy regimes in line with the VAR evidence. Second, the model should ideally capture the large inflationary consequences of fiscal imbalances during the zero-lower-bound regime. At the same time, this zero-lower-bound regime should also be inherently different from any other regime to the extent that a policy change is triggered by a large contractionary shock. Third, a successful model should be able to capture the core of the macroeconomic comovements during the Great Recession as the result of this single large initial shock and the associated change in policymakers' behavior.

We construct and estimate a dynamic general equilibrium model that reflects these findings and captures a key policy trade-off that arises at the zero lower bound: 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 central bank reacts strongly to deviations of inflation from its target, whereas the fiscal authority passively accommodates the behavior of the monetary authority by adjusting primary surpluses to keep debt on a stable path. If agents expect this regime to prevail for a long time, any fiscal imbalance is backed by future fiscal adjustments and the economy is largely insulated with respect to these disturbances. Under the *fiscally-led policy mix*, the fiscal authority does not react strongly enough to debt fluctuations. It is now the monetary authority that passively accommodates the behavior of the fiscal authority by allowing inflation and real activity to move so as to stabilize debt.¹ Finally, the economy is occasionally hit by a large demand shock that forces policymakers into a *zero-lower-bound regime* in which the central bank sets the interest rate to zero and the fiscal

¹In 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.

authority temporarily disregards the level of debt.

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 parameter that controls agents' beliefs about policymakers' exit strategy. We find that during the recent crisis the probability assigned to a switch to the fiscally-led regime experienced a noticeable increase, even if agents still regard a return to the monetary-led regime as more likely (around 92%). While the estimated probability of a switch to the fiscally-led regime remains relatively low, the inflationary pressure deriving from the large stock of debt is enough to prevent the economy from experiencing deflation. Thus, uncertainty about the future monetary and fiscal policy mix can account for the lack of deflation. To show this, we run a counterfactual simulation in which policy uncertainty is removed. As in the standard New Keynesian model, this counterfactual model predicts a large deflation.

The last part of the paper is devoted to highlighting a policy trade-off that arises at the zero lower bound. To this end, we study the consequences of fully credible announcements about policymakers' future behavior in the aftermath of the large demand shock. If policymakers announce the monetary-led regime, inflation expectations drop, leading to deflation and a severe recession. If instead policymakers announce that they will move to the fiscally-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 lifts the economy out of the recession. However, such an announcement would also increase macroeconomic volatility once the economy is out of the recession. This happens because under this regime the macroeconomy is not insulated anymore with respect to fiscal disturbances. Thus, a policy trade-off between mitigating the recession and preserving long-run macroeconomic stability arises at the zero lower bound. As views of the relative importance of the two goals differ, so do the policy prescriptions, with the result that policy uncertainty is likely to arise at the zero lower bound.

Other papers have addressed the Hall's puzzle (King and Watson 2012; Del

Negro et al. 2015) and have proposed resolutions (Christiano et al. 2015 and Coibion and Gorodnichenko 2015). The novelty of this paper is to show that policy uncertainty about the way debt will be stabilized can account for the lack of deflation during the Great Recession. This mechanism also allows us to explain why inflation expectations rose between 2009 and 2011. 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 et al. 2000; Lubik and Schorfheide 2004; and Bianchi 2013). Baker et al. (2016) construct a comprehensive index of policy uncertainty. Fernandez-Villaverde, Guerron-Quintana, et al. (2015) study the role of fiscal volatility in slowing down the recovery during the current crisis. However, fiscal volatility shocks do not provide an explanation for the absence of deflation observed in the data, whereas the uncertainty about future policy rules considered in this paper does.

Our work is related to the vast literature on the zero lower bound.² Our work differs from previous contributions in one or more of the following dimensions. First, we conduct a structural estimation of a general equilibrium model and investigate the effects of policy uncertainty at the zero lower bound. In this respect, the paper is related to the literature on the macroeconomic effects of uncertainty (Bloom 2009, Gilchrist et al. 2014, Fernandez-Villaverde et al. 2011, Basu and Bundick 2012). Second, we work in a stochastic environment 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 dynamic stochastic general equilibrium (DSGE).

Finally, our work is related to the study of the interaction between fiscal and

²See Benhabib et al. (2001, 2002), Mertens and Ravn (2014), Fernandez-Villaverde, Gordon, et al. (2015), Fernandez-Villaverde et al. (2014), Coibion et al. (2012), Werning (2012), Correia et al. (2013), Gust et al. (2013), Aruoba and Schorfheide (2013).

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; Reis 2016). In this respect this paper is related to Bianchi and Ilut (2015) and Bianchi and Melosi (2013), but differs from these two papers across several dimensions. First, we here allow for the zero lower bound and show that policy uncertainty can account for the absence of deflation during the Great Recession. 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 use a Markov-switching VAR to establish a series of stylized facts about the zero lower bound and the 60 years of data that preceded it.

This paper is organized as follows. Section 2 presents the stylized facts based on the Markov-switching VAR. These results are used to motivate the benchmark model presented in Section 3. Section 4 shows that policy uncertainty can account for the lack of deflation. Section 5 compares the benchmark model to a nested model in which policy uncertainty is removed. Section 6 outlines the policy trade-off that arises at the zero lower bound. Section 7 concludes.

2 Motivating Evidence

We introduce a Markov-switching VAR (MS-VAR) to motivate the key mechanism studied in this paper; that is, the growing US fiscal imbalances can account for why inflation did not persistently drop during the Great Recession. With respect to the seminal contribution by Sims and Zha (2006), our MS-VAR includes a measure of the US fiscal stance. This reduced-form analysis will also be valuable for designing a structural model to study the last eight years of data.

Estimating Bayesian VAR models with Markov-switching parameters proves to become quickly computationally challenging as the number of observables and lags grows. We therefore opt for a parsimonious specification with two lags, four observables, and quarterly data. This is in line with the literature that allows for smoothly time-varying parameters in VARs (Primiceri 2005, Cogley and Sargent 2006). We include GDP growth, inflation, and the federal funds

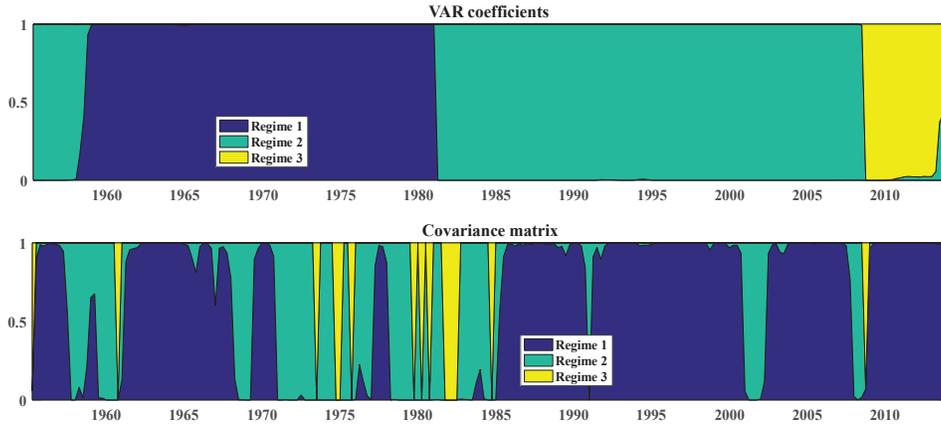


Figure 1: **Smoothed Probabilities of Regimes of MS-VAR.** The top panel reports the probabilities for the three regimes characterizing the VAR coefficients, whereas the lower panel reports the probabilities for the three regimes of the covariance matrix.

rate (FFR) to capture the behavior of the macroeconomy. We then add the ratio of primary deficit-to-debt as a parsimonious observable that captures the fiscal stance of the US government over time. In order for debt to be fiscally sustainable, this ratio needs to be negative on average, as the fiscal authority needs to run primary surpluses.³ We allow for three Markov-switching regimes for the constants and the autoregressive parameters and three Markov-switching regimes for the volatility of the innovations:

$$Z_t = c_{\xi_t^\Phi} + A_{\xi_t^\Phi,1}Z_{t-1} + A_{\xi_t^\Phi,2}Z_{t-2} + \Sigma_{\xi_t^\Sigma}^{1/2}\omega_t \quad (1)$$

$$\Phi_{\xi_t^\Phi} = \left[c_{\xi_t^\Phi}, A_{\xi_t^\Phi,1}, A_{\xi_t^\Phi,2} \right], \omega_t \sim N(0, I) \quad (2)$$

where Z_t is an $(n \times 1)$ vector of data. The unobserved states ξ_t^Φ and ξ_t^Σ control the regimes in place for the VAR coefficients and the covariance matrix, respectively. The regimes evolve according to two transition matrices, H^Φ and H^Σ . Since we want to keep this analysis as agnostic as possible, we do not impose any ex-ante restrictions on the property of these regimes. Therefore, we estimate the MS-VAR model by using Bayesian techniques with flat priors.

³Other VAR studies have used this ratio as an observable. See Sims (2010b) and Kliem et al. (2016). Appendix A contains details about the model, the dataset, and the estimation.

| Conditional Steady States | | | | | | |
|---------------------------|----------|------|------|----------|-------|-------|
| | Regime 1 | | | Regime 2 | | |
| | Median | 16% | 84% | Median | 16% | 84% |
| Deficit/Debt | 2.99 | 1.44 | 6.21 | -3.63 | -8.72 | -0.49 |
| GDP Growth | 3.45 | 1.91 | 4.25 | 3.00 | 2.69 | 3.28 |
| Inflation | 5.11 | 3.45 | 8.61 | 2.48 | 2.06 | 2.81 |
| Interest Rate | 6.15 | 4.87 | 8.89 | 4.68 | 3.53 | 5.83 |
| Real Interest Rate | 1.07 | 0.23 | 1.48 | 2.21 | 1.27 | 3.21 |

Table 1: Conditional steady states implied by the MS-VAR. For each draw of the VAR coefficients we compute the implied conditional steady states. These represent the values to which the observable converge once a regime is in place for a prolonged period of time.

Figure 1 reports the smoothed probabilities at the posterior mode for the three regimes controlling the VAR coefficients and the three regimes of the covariance matrix. As far as the covariance matrix, Appendix A shows that the three regimes imply increasing levels of volatility. Regime 2 can be thought of as a regime associated with recessions and the turbulent periods of the 1970s until the beginning of the Great Moderation, which is instead dominated by the low volatility Regime 1. The volatility Regime 3 captures exceptional events, like the acceleration of the Great Recession in 2008Q3. However, we are mostly interested in the dynamics captured by the regimes for the VAR coefficients. Regime 1 dominates the 1960s and the 1970s. The switch from Regime 1 to Regime 2 occurs in 1981Q2. In order to understand what distinguishes these two regimes, Table 1 reports their conditional steady states. These are the values to which the variables converge if a regime is in place for a prolonged period of time. Regime 1 is characterized by primary deficits, as opposed to primary surpluses under Regime 2, higher inflation, and a lower real interest rate.

In order to understand the role of regime changes in capturing the properties of the data, Figure 2 presents a simulation in which all Gaussian shocks are set to zero and only regime changes occur. The light gray area and the dark gray area correspond to the periods during which Regime 1 and Regime 3 were in place, respectively. The early switch from Regime 2 to Regime 1 captures the low frequency increase in inflation that occurred starting in the late 1960s and that lasted until the Volcker disinflation of the early 1980s. This low frequency increase in inflation is associated with a similar low frequency movement in the

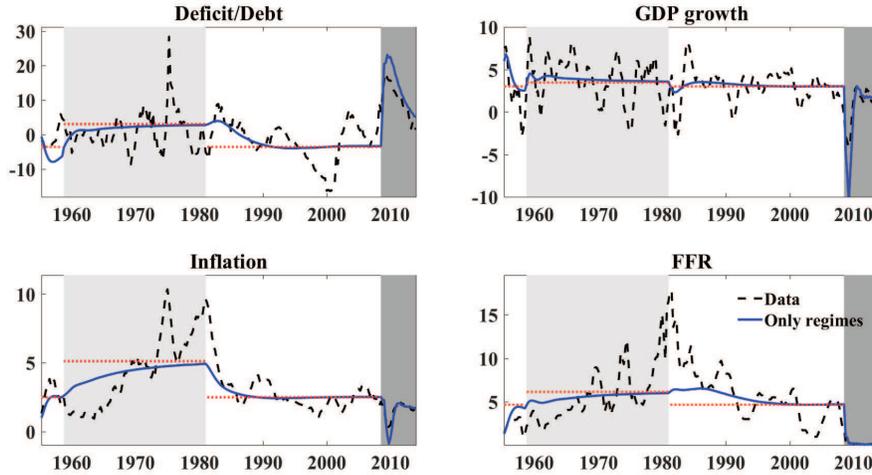


Figure 2: **Effects of regime changes.** The figure presents a simulation in which all Gaussian shocks are set to zero and only regime changes occur. The light gray area and the dark gray area correspond to the periods during which Regime 1 and Regime 3 were in place, respectively. The dashed line corresponds to the data, whereas the dotted line corresponds to the conditional steady states for Regime 1 and Regime 2.

deficit-to-debt ratio that stabilizes around a positive value. The increase in the federal funds rate is visibly smaller than the increase in inflation. This is in line with the drop in the conditional steady state of the real interest rate presented in Table 1. As will become clear when considering the structural model, these stylized facts can be rationalized in light of a change in the monetary-fiscal policy mix from fiscally-led to monetary-led. Under Regime 1, higher deficits lead to higher average inflation. Real interest rates remain low because the monetary authority does not react aggressively to inflation. We refer to Regime 1 as the fiscally-led regime and Regime 2 as the monetary-led regime.⁴

Regime 3 dominates the last part of the sample starting in 2008Q3. This quarter marks the acceleration of the financial crisis and the worst period of the Great Recession. The large contraction in real activity prompted policymakers to take extraordinary actions on both the monetary and the fiscal sides. The

⁴This interpretation of the data is consistent with Bianchi and Ilut (2015), who find a similar sequence of regime changes for the pre-crisis period when estimating a microfounded model. They identify a switch from a fiscally-led regime, which characterized the 1960s and 1970s, to a monetary-led regime exactly in 1981:Q2, after the appointment of Volcker as Fed Chairman and Reagan's election as President of the United States.

fiscal authority swiftly introduced massive measures of fiscal stimulus that raised the deficit-to-debt ratio by 11 percentage points within the next three quarters. The Federal Reserve cut the FFR aggressively to reach the zero lower bound. Consequently, we label Regime 3 the zero-lower-bound regime. At the end of the sample, we observe an increase in the probability of Regime 2, which we interpret as the monetary-led regime. However, Regime 3 is still the most likely regime. Furthermore, this result is in part driven by end-of-sample uncertainty.

Our MS-VAR model explains the key macroeconomic dynamics during the Great Recession and the ensuing slow recovery as a result of the shock that pushed the economy from the monetary-led regime to the zero-lower-bound regime in 2008:Q3. To highlight this point, Figure 3 extends the previous analysis by focusing on the effects of entering the zero-lower-bound regime in 2008:Q3. All Gaussian shocks are still shut down in this simulation and the starting point is 2008:Q3. The 70% posterior bands (gray areas) for the effects of this discrete shock capture remarkably well the dynamics of the data (solid line). This result suggests that the dynamics of the macroeconomy during the Great Recession can in principle be explained by only one adverse discrete shock. This shock lowered both output growth and inflation for a few quarters while it triggered radical and persistent changes in the conduct of fiscal and monetary policies. The switch to the zero-lower-bound regime seems to capture all of these stylized facts.

Of particular interest is the quick deterioration of the fiscal position as the Great Recession started. A crucial question for this paper is whether these fiscal imbalances had noticeable effects on price dynamics during the zero-lower-bound period. The following exercise serves the purpose of providing evidence of the key mechanism studied in this paper and hence motivates our ensuing structural analysis. We compute the response of inflation to fiscal shocks in the estimated MS-VAR so as to assess the inflationary consequences (if any) of the quickly deteriorating fiscal position during the Great Recession. We identify fiscal shocks as those shocks that raise the deficit-to-debt ratio upon impact while stimulating the economy for at least 5 quarters.⁵ The positive comovement

⁵We restrict the deficit-to-debt ratio to respond positively *only upon impact* to accommodate the fact that primary deficits tend to be countercyclical and that fiscal rules, whose

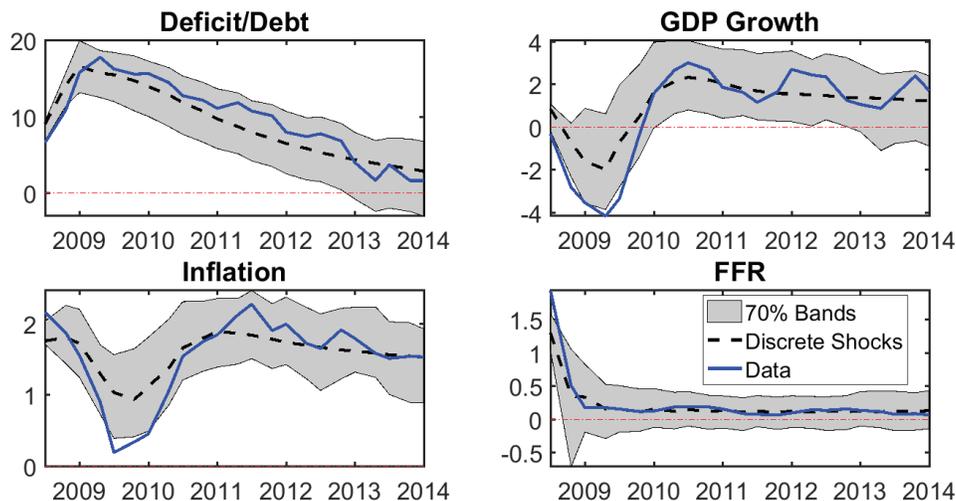


Figure 3: **Entering the zero-lower-bound regime.** The blue solid line reports the actual data. The black dashed line denotes the posterior median of the variables simulated from the MS-VAR by using only the dynamics implied by the VAR coefficients under Regime 3 starting in 2008:Q3. We initialize the simulations by using the actual value of the observables in 2008Q2. The gray areas capture the 70% posterior set of the simulated variables.

between deficit dynamics and GDP growth is the salient identifying feature of fiscal shocks. Non-fiscal shocks that affect economic activity, such as technology shocks, should arguably lead to a negative comovement between deficit and GDP growth, given that tax revenues go down during recession, while transfers tend to increase.

The results are reported in Figure 4, which shows three snapshots of the macroeconomic effects of fiscal shocks before, at, and after the onset of the Great Recession. These findings suggest that the inflationary effects of a growing fiscal imbalance due to the Great Recession may have been fairly sizable. The plots report a fiscal shock that raises the deficit-to-debt ratio by slightly more than one percentage point in 2008:Q3. In the data this ratio went up by more than four percentage points in 2008:Q3 and 11.20 percentage points from 2008:Q3 through 2009:Q2 (peak). Consequently, it is conceivable that the deterioration

objectives are to stabilize the business cycles, feature feedbacks to the real economy. Also, a higher deficit today will imply a higher stock of debt tomorrow, making the impact of fiscal shocks on this observable variable ambiguous ex-ante. As is standard in the structural VAR literature, this identification scheme is consistent with our DSGE model.

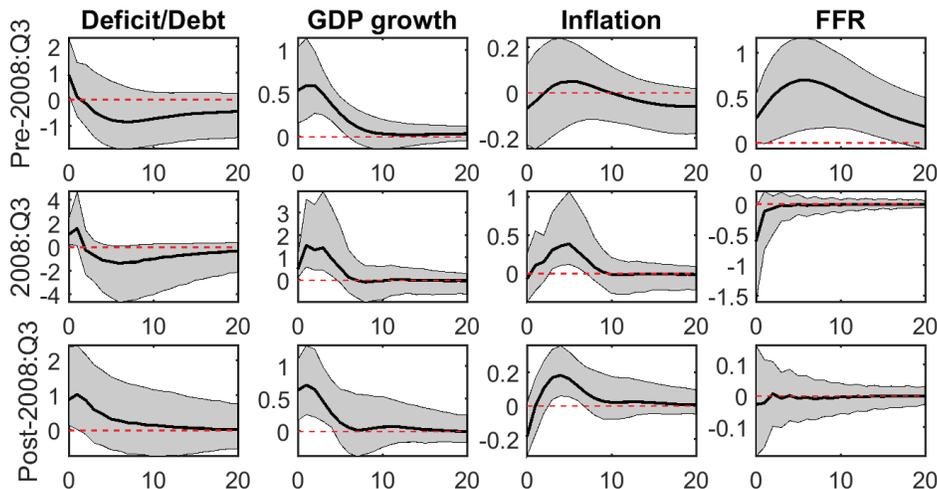


Figure 4: **Fiscal shocks before and at the zero lower bound.** The solid line denotes the posterior median of the response of the observable variables to a one-standard-deviation fiscal shock that raises the deficit-to-debt ratio upon impact and GDP growth within the next five quarters. Gray areas denote the 70% posterior set for the responses.

in the government’s fiscal position observed in the data contributed to raising inflation quite substantially in the first quarters of the Great Recession.

Another interesting finding is that fiscal imbalances started to have inflationary consequences only in 2008:Q3, that is, when the zero-lower-bound regime arises. Before that period, the inflationary implications of fiscal imbalances are found to be statistically not significant (see upper panel in Figure 4). Before the Great Recession, the Federal Reserve was used to raising the rate relatively aggressively in response to fiscal shocks and in doing so kept a firm control over price dynamics. Furthermore, when the zero lower bound becomes binding in post-2008:Q3, the impact of fiscal imbalances on inflation was reduced as the Federal Reserve could not lower the rate further as it did in 2008:Q3.

The findings presented in this section suggest that the following are desirable properties for a structural model whose objective is to study the Great Recession. First, a successful model should be able to explain the dynamics of macro aggregates during the Great Recession as the result of a single large initial shock. Second, the model should feature three policy regimes as the VAR clearly identifies a switch to a third regime once the Great Recession began and two distinct periods before that. Third, the model should ideally capture the

large inflationary consequences of fiscal imbalances during the zero-lower-bound regime. This third regime should be characterized by extremely low variability in the policy rate and hence must be different from the regimes that were in place before the crisis. Even if this third regime should feature an important role for fiscal imbalances, it should be associated with the realization of a large negative demand shock, unlike the fiscally-led regime that arose in the 1960s and 1970s. In the next section, we build a model in line with these key properties.

3 A Model with Policy Uncertainty

In this section we introduce the model that we will fit to US data in order to quantify the importance of policy uncertainty. The model is obtained by augmenting the prototypical New Keynesian model with a fiscal block and a discrete shock that can push the economy to the zero lower bound (ZLB).

3.1 A New Keynesian model

Households. The representative household maximizes expected utility:

$$E_0 \left[\sum_{s=0}^{\infty} \beta^s \exp(\zeta_t^d) [\log(C_t - \Phi C_{t-1}^A) - h_t] \right] \quad (3)$$

subject to the budget constraint:

$$P_t C_t + P_t^m B_t^m + P_t^s B_t^s = P_t W_t h_t + B_{t-1}^s + (1 + \rho P_t^m) B_{t-1}^m + P_t D_t - T_t + TR_t$$

where D_t stands for real dividends paid by the firms, C_t is consumption, h_t is hours, W_t is the real wage, T_t is taxes, TR_t stands for transfers, and C_t^A represents the average level of consumption in the economy. The parameter Φ captures the degree of external habit. Following Woodford (2001), we assume that there are two types of government bonds: one-period government debt, B_t^s , in zero net supply with price P_t^s and a more general portfolio of government debt, B_t^m , in non-zero net supply with price P_t^m . The former debt instrument satisfies $P_t^s = R_t^{-1}$. The latter debt instrument has payment structure $\rho^{T-(t+1)}$

for $T > t$ and $0 < \rho < 1$. The asset can be interpreted as a portfolio of infinitely many bonds with average maturity controlled by the parameter ρ . The value of such an instrument issued in period t in any future period $t+j$ is $P_{t+j}^{m-j} = \rho^j P_{t+j}^m$.

The preference shock ζ_d is the sum of a continuous and discrete component: $\zeta_d = d_t + \bar{d}_{\xi_t^d}$. The continuous component d_t follows an AR(1) process: $d_t = \rho_d d_{t-1} + \sigma_d \varepsilon_{d,t}$. The discrete component $\bar{d}_{\xi_t^d}$ can assume two values: high or low (\bar{d}_h or \bar{d}_l). The variable ξ_t^d controls the regime in place and evolves according to the transition matrix H^d :

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

where $p_{ji} = P(\xi_{t+1}^d = j | \xi_t^d = i)$. The values of H^d , \bar{d}_h , and \bar{d}_l are such that the unconditional mean of the discrete shock $\bar{d}_{\xi_t^d}$ is zero. This specification is in the spirit of Christiano et al. (2011). However, in the current setup shocks to preferences that are able to trigger the ZLB are assumed to be recurrent, and agents take into account that these episodes can lead to unusual policymakers' responses, as discussed later on.

Firms. The representative firm j faces a downward-sloping demand curve, $Y_t(j) = (P_t(j)/P_t)^{-1/v_t} Y_t$, where the parameter $1/v_t$ is the elasticity of substitution between two differentiated goods. Firms take as given the general price level, P_t , and the level of real activity, Y_t . Whenever a firm changes its price, it faces a quadratic adjustment cost:

$$AC_t(j) = .5\varphi (P_t(j)/P_{t-1}(j) - \Pi)^2 Y_t(j) P_t(j) / P_t \quad (4)$$

where $\Pi_t = P_t/P_{t-1}$ is gross inflation at time t and Π is the corresponding deterministic steady state. Shocks to the elasticity of substitution imply shocks to the markup $\aleph_t = 1/(1 - v_t)$. We assume that the rescaled markup $\mu_t = \kappa \log(\aleph_t/\aleph)$ follows an autoregressive process, $\mu_t = \rho_\mu \mu_{t-1} + \sigma_\mu \varepsilon_{\mu,t}$, where $\kappa \equiv \frac{1-v}{v\varphi\Pi^2}$ is the slope of the Phillips curve. The firm chooses the price $P_t(j)$ to maximize the present value of future profits:

$$E_t \left[\sum_{s=t}^{\infty} Q_s ([P_s(j)/P_s] Y_s(j) - W_s h_s(j) - AC_s(j)) \right]$$

where Q_s is the marginal value of a unit of consumption good. Labor is the only input in the firm production function, $Y_t(j) = A_t h_t^{1-\alpha}(j)$, where total factor productivity A_t evolves according to an exogenous process: $\ln(A_t/A_{t-1}) = \gamma + a_t$, $a_t = \rho_a a_{t-1} + \sigma_a \varepsilon_{a,t}$, $\varepsilon_{a,t} \sim N(0, 1)$.

Government. Imposing the restriction that one-period debt is in zero net supply, the flow budget constraint of the federal government is given by:

$$P_t^m B_t^m = B_{t-1}^m (1 + \rho P_t^m) - T_t + E_t + TP_t$$

where $P_t^m B_t^m$ is the market value of debt and T_t and E_t represent federal tax revenues and federal expenditures, respectively. Government expenditure is the sum of federal transfers and goods purchases: $E_t = P_t G_t + TR_t$. The term TP_t is a shock that is meant to capture a series of features that are not explicitly modeled here, such as changes in the maturity structure and the term premium. This shock is necessary because we treat all the components of the government budget constraint as observables. We rewrite the federal government budget constraint in terms of debt-to-GDP ratio $b_t^m = (P_t^m B_t^m) / (P_t Y_t)$:

$$b_t^m = (b_{t-1}^m R_{t-1,t}^m) / (\Pi_t Y_t / Y_{t-1}) - \tau_t + e_t + tp_t$$

where $R_{t-1,t}^m = (1 + \rho P_t^m) / P_{t-1}^m$ is the realized return of the maturity bond, all the variables are expressed as a fraction of GDP, and we assume $tp_t = \rho_{tp} tp_{t-1} + \sigma_{tp} \varepsilon_{tp,t}$, $\varepsilon_{tp,t} \sim N(0, 1)$.

The linearized transfers as a fraction of GDP, \tilde{tr}_t , follow the following process:

$$\begin{aligned} (\tilde{tr}_t - \tilde{tr}_t^*) &= \rho_{tr} (\tilde{tr}_{t-1} - \tilde{tr}_t^*) + (1 - \rho_{tr}) \phi_y (\hat{y}_t - \hat{y}_t^*) + \sigma_{tr} \varepsilon_{tr,t} \\ \tilde{tr}_t^* &= \rho_{tr^*} \tilde{tr}_{t-1}^* + \sigma_{tr^*} \varepsilon_{tr^*,t}, \quad \varepsilon_{tr^*,t} \sim N(0, 1), \quad \varepsilon_{tr,t} \sim N(0, 1) \end{aligned}$$

where \tilde{tr}_t^* represents a long-term component that is meant to capture the large programs that arise as the result of a political process that is not modeled here.⁶ Transfers move around this trend component as a result of business cycle

⁶In what follows, \hat{x}_t denotes the percentage deviation of a detrended variable from its own steady state. For all the variables normalized with respect to GDP (debt, expenditure, and taxes) \tilde{x}_t denotes a linear deviation, while for all the other variables \tilde{x}_t denotes a percentage

fluctuations captured by the log-linearized output gap $(\hat{y}_t - \hat{y}_t^*)$, where \hat{y}_t^* is potential output. The government also buys a fraction G_t/Y_t of total output. We define $g_t = 1/(1 - G_t/Y_t)$ and we assume that $\tilde{g}_t = \ln(g_t/g)$ follows an autoregressive process: $\tilde{g}_t = \rho_g \tilde{g}_{t-1} + \sigma_g \epsilon_{g,t}$, $\epsilon_{g,t} \sim N(0, 1)$.

Policy Rules. When the high value for the preference shock is realized ($\xi_t^d = h$), the economy is out of the ZLB and monetary and fiscal policies are not constrained. In this case, the central bank follows a standard Taylor rule and the evolution of the policy mix can be described by a two-regime Markov switching process ξ_t^p , whose properties will be described in the next section. When the low value for the preference shock is realized ($\xi_t^d = l$), the central bank lowers the FFR until the ZLB is reached and the fiscal authority focuses on stabilizing the economy as opposed to trying to stabilize the stock of debt.

Specifically, the monetary policy rule reads as follows:

$$R_t/R = \left(1 - Z_{\xi_t^d}\right) (R_{t-1}/R)^{\rho_{R,\xi_t^p}} \left[(\Pi_t/\Pi)^{\psi_{\pi,\xi_t^p}} (Y_t/Y_t^*)^{\psi_{y,\xi_t^p}} \right]^{(1-\rho_{R,\xi_t^p})} e^{\sigma_R \epsilon_{R,t}} + Z_{\xi_t^d} (R_{t-1}/R)^{\rho_{R,Z}} (1/R)^{(1-\rho_{R,Z})} \psi_Z e^{\sigma_Z \epsilon_{R,t}} \quad (5)$$

where $\epsilon_{R,t} \sim N(0, 1)$, R is the steady-state gross nominal interest rate, Y_t^* is the output target, and Π is the deterministic steady-state level for gross inflation. The parameters ψ_{π,ξ_t^p} and ψ_{y,ξ_t^p} capture the central bank's response to inflation and output gap, which depends on the policy mix ξ_t^p in place at time t . The dummy variable $Z_{\xi_t^d}$ is zero when the value of the preference shock is high ($\xi_t^d = h$) and one when it is low ($\xi_t^d = l$). To match the behavior of the FFR in the data during the zero-lower-bound period, we need to allow for small disturbances and a gradual decline toward a value close, but not exactly equal, to zero. The size of the monetary policy shocks at the ZLB, σ_Z , is assumed to be a tenth of the standard deviation of the monetary policy shocks when out of the ZLB: $\sigma_Z = \sigma_R/10$. The persistence of changes in the federal funds rate at the ZLB is controlled by $\rho_{R,Z}$ and fixed to .2. Finally, the parameter $0 < \psi_Z \leq 1$ controls the average level of the FFR when at the ZLB. It can be thought of as the fraction of the steady-state net interest rate. Notice that if

deviation.

we set $\sigma_Z = 0$, $\rho_{R,Z} = 0$, and $\psi_Z = 1$, we would obtain $R_t = 1$ at the ZLB and the net nominal interest rate would be exactly zero.⁷

The fiscal authority moves taxes according to the following rule:

$$\begin{aligned} \tilde{\tau}_t = & \left(1 - Z_{\xi_t^d}\right) \left[\rho_{\tau, \xi_t^p} \tilde{\tau}_{t-1} + \left(1 - \rho_{\tau, \xi_t^p}\right) \left[\delta_{b, \xi_t^p} \tilde{b}_{t-1}^m + \delta_e \tilde{e}_t^* + \delta_y (\hat{y}_t - \hat{y}_t^*) \right] \right] \\ & + Z_{\xi_t^d} \left[\rho_{\tau, Z} \tilde{\tau}_{t-1} + \left(1 - \rho_{\tau, Z}\right) \left[\delta_e \tilde{e}_t^* + \delta_y (\hat{y}_t - \hat{y}_t^*) \right] \right] + \sigma_\tau \epsilon_{\tau, t} \end{aligned} \quad (6)$$

where $\tilde{e}_t^* \equiv \tilde{tr}_t^* + g^{-1} \tilde{g}_t$, $\epsilon_{\tau, t} \sim N(0, 1)$, and $\tilde{\tau}_t$ is the level of tax revenues with respect to GDP in deviations from the steady state. When the economy is in the high state of demand ($Z_{\xi_t^d} = 0$), tax revenues respond to the state of the economy, captured by the output gap, to the sum of the long-run level of transfers and government purchases, and to the level of debt. The parameter δ_{b, ξ_t^p} captures the fiscal authority's attitude toward debt stabilization, which depends on the type of policy mix ξ_t^p in place at time t . When the large negative preference shock hits ($Z_{\xi_t^d} = 1$), the fiscal authority temporarily disregards the level of debt to focus on stabilizing the economy. However, the fiscal authority still responds to the level of spending.

3.2 Policy changes

To characterize policymakers' behavior out of the ZLB, we will make use of the partition of the parameter space introduced by Leeper (1991). For the sake of the exposition, we will assume that the Taylor rule reacts only to inflation, whereas the fiscal rule reacts only to debt. In this simplified version of the model, we can distinguish four regions 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

⁷When estimating the model we verify that the ZLB would be binding in response to the large negative preference shock. Our approach to modeling the ZLB differs from the conventional one, 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 the possibility of states of the world in which the nominal rate R_t assumes negative values, it has the advantage of keeping the model tractable while it allows us to study the consequences of policy uncertainty.

Fiscal (AM/PF), is the most familiar one: The Taylor principle is satisfied and the fiscal authority moves taxes to keep debt on a stable path: $\psi_{\pi}^{AM} > 1$ and $\delta_b^{PF} > \beta^{-1} - 1$. We refer to this policy combination as the monetary-led regime.

The second determinacy region, Passive Monetary/Active Fiscal (PM/AF), corresponds to the case in which the fiscal authority is not committed to stabilizing the process for debt: $\delta_b^{AF} < \beta^{-1} - 1$. 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: $\psi_{\pi}^{PM} < 1$. 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 label this policy combination the fiscally-led regime. Finally, when both authorities are active, no stationary equilibrium exists, whereas when both of them are passive, the economy is subject to multiple equilibria.

In the benchmark model, when the preference shock is high ($\xi_t^d = h$), the economy is out of the ZLB ($Z_{\xi_t^d} = 0$) 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 $p_{ji} = P(\xi_{t+1}^p = j | \xi_t^p = i)$. 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*: $\psi_{\pi,M} = \psi_{\pi}^{AM} > 1$ and $\delta_{b,M} = \delta_b^{PF} > \beta^{-1} - 1$. Regime F is the *fiscally-led regime*: $\psi_{\pi,F} = \psi_{\pi}^{PM} < 1$ and $\delta_{b,F} = \delta_b^{AM} < \beta^{-1} - 1$.

When the low value for the preference shock occurs ($\xi_t^d = l$), the ZLB becomes binding ($Z_{\xi_t^d} = 1$), and policymakers' behavior is now constrained. In this third regime, the central bank lowers the FFR until it hits the ZLB and the fiscal authority temporarily disregards the level of debt in order to focus on stabilizing the economy.⁸ Notice that the zero-lower-bound policy mix can

⁸Our results are robust to relaxing the assumption regarding the behavior of the fiscal

be considered as an extreme version of the fiscally-led policy mix. However, while out of the ZLB, switches to the fiscally-led regime capture the deliberate choices of policymakers, the zero-lower-bound regime is triggered 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, policymakers' behavior is not constrained anymore.

Even if the ZLB imposes a constraint on policymakers' behavior, agents' beliefs are not constrained. Therefore, beliefs about the exit strategy and policy uncertainty are going to be key to understanding the macroeconomic dynamics at the ZLB. To capture this feature, we introduce a parameter controlling the expected exit strategy from the ZLB. The parameter p_{ZM} represents the probability that once the discrete preference shock is reabsorbed, the economy will move to the the monetary-led regime.

The joint evolution of policymakers' behavior and the discrete preference shock is controlled by the combined chain $\xi_t \equiv [\xi_t^p, \xi_t^d] = \{[M, h], [F, h], [Z, l]\}$. The corresponding transition matrix H is obtained by combining the transition matrices H^d and H^p with the parameter p_{ZM} :

$$H = \begin{bmatrix} p_{hh}H^p & (1 - p_u) \begin{bmatrix} p_{ZM} \\ 1 - p_{ZM} \end{bmatrix} \\ (1 - p_{hh}) [1, 1] & p_u \end{bmatrix}.$$

3.3 Solving the MS-DSGE model

The technology process A_t is assumed to have a unit root. The model is then rescaled and linearized around the unique deterministic steady state. The model can be solved with any of the solution methods developed for Markov-switching DSGE models. We use the solution method of Farmer et al. (2009). It is worth emphasizing that in our model, agents form expectations while taking into account the possibility of entering the ZLB and of changes in policymakers' behavior. Furthermore, they understand that entering the ZLB is an event induced by an exogenous shock that can modify policymakers' behavior even authority because the dynamics at the zero lower bound mostly depend on the exit strategy.

once the constraint stops being 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 ZLB. The solution can be characterized as a MS-VAR:

$$S_t = c(\xi_t, \theta, H) + T(\xi_t, \theta, H) S_{t-1} + R(\xi_t, \theta, H) Q(\theta^v) \varepsilon_t \quad (7)$$

where θ , θ^v , and S_t are vectors that contain the structural parameters, the stochastic volatilities, and all the variables of the model, respectively. Appendix B provides more details about the linearization and the solution algorithm.

It is worth emphasizing that the law of motion of the model depends on the structural parameters (θ), the regime in place (ξ_t), and the probability of moving across regimes (H). This notation highlights that the properties of one regime depend not only on the structural parameters describing that particular regime, but also on what agents expect is going to happen under alternative regimes and on how likely it is that a regime change will occur in the future (see also Davig and Leeper 2007). In other words, agents' beliefs about future regime changes matter for the law of motion governing the economy.

4 The Effects of Policy Uncertainty

The model solution is combined with a system of observation equations. We estimate the model with Bayesian methods. We include seven observables spanning the sample 1954:Q4-2014:Q1: real GDP growth, annualized GDP deflator inflation, annualized FFR, annualized debt-to-GDP ratio, federal tax revenues to GDP ratio, federal expenditure to GDP ratio, and a transformation of government purchases to GDP ratio. All variables are expressed in percentage points when reporting the results. For tractability, we fix the regime sequence for the out-of-the-zero-lower-bound regimes based on the VAR evidence presented in Section 2. The zero-lower-bound regime is assumed to start in 2008:Q4 and remains in place until the end of the sample.⁹

⁹As the starting date of the ZLB we choose 2008:Q4, instead of 2008:Q3 as implied by the MS-VAR, in light of a model comparison exercise in which we considered all quarters between

| | Mean | 5% | 95% | Type | Mean | Std |
|------------------|---------|---------|---------|------|-------|--------|
| $\psi_{\pi,M}$ | 1.6019 | 1.1758 | 2.0207 | N | 2.5 | 0.3 |
| $\psi_{y,M}$ | 0.5065 | 0.2980 | 0.7688 | G | 0.4 | 0.2 |
| $\rho_{R,M}$ | 0.8652 | 0.8135 | 0.9108 | B | 0.5 | 0.2 |
| $\delta_{b,M}$ | 0.0712 | 0.0457 | 0.1041 | G | 0.07 | 0.02 |
| $\rho_{\tau,M}$ | 0.9652 | 0.9439 | 0.9816 | B | 0.5 | 0.2 |
| $\psi_{\pi,F}$ | 0.6356 | 0.5007 | 0.7546 | G | 0.8 | 0.3 |
| $\psi_{y,F}$ | 0.2709 | 0.2005 | 0.3458 | G | 0.15 | 0.1 |
| $\rho_{R,F}$ | 0.6663 | 0.5927 | 0.7401 | B | 0.5 | 0.2 |
| $\rho_{\tau,F}$ | 0.6874 | 0.5358 | 0.8438 | B | 0.5 | 0.2 |
| d_l | -0.3662 | -0.4827 | -0.2789 | N | -0.3 | 0.1 |
| p_{hh} | 0.9995 | 0.9984 | 0.9999 | D | 0.96 | 0.03 |
| p_{ll} | 0.9306 | 0.8936 | 0.9599 | D | 0.83 | 0.10 |
| p_{MM} | 0.9923 | 0.9872 | 0.9965 | D | 0.96 | 0.03 |
| p_{FF} | 0.9923 | 0.9888 | 0.9951 | D | 0.96 | 0.03 |
| p_{ZM} | 0.9225 | 0.8108 | 0.9861 | D | 0.50 | 0.22 |
| ψ_Z | 0.9678 | 0.9596 | 0.9761 | B | 0.95 | 0.02 |
| κ | 0.0073 | 0.0052 | 0.0098 | G | 0.3 | 0.15 |
| ρ_{tr} | 0.4599 | 0.3677 | 0.5537 | B | 0.2 | 0.05 |
| δ_y | 0.2766 | 0.1899 | 0.3707 | N | 0.4 | 0.2 |
| δ_e | 0.3661 | 0.2096 | 0.5137 | N | 0.5 | 0.2 |
| ϕ_y | -0.2910 | -0.3433 | -0.2435 | N | -0.4 | 0.2 |
| Φ | 0.8628 | 0.8299 | 0.8928 | B | 0.5 | 0.2 |
| ρ_g | 0.9796 | 0.9742 | 0.9839 | B | 0.5 | 0.2 |
| ρ_a | 0.4053 | 0.1522 | 0.6480 | B | 0.5 | 0.2 |
| ρ_d | 0.3944 | 0.2881 | 0.4963 | B | 0.5 | 0.2 |
| ρ_{tp} | 0.3267 | 0.2276 | 0.4218 | B | 0.5 | 0.2 |
| ρ_μ | 0.4784 | 0.4053 | 0.5513 | B | 0.5 | 0.2 |
| $100\sigma_R$ | 0.1934 | 0.1767 | 0.2115 | IG | 0.5 | 0.5 |
| $100\sigma_g$ | 0.2826 | 0.2614 | 0.3049 | IG | 1.00 | 1.00 |
| $100\sigma_a$ | 0.7708 | 0.4713 | 1.1552 | IG | 1.00 | 1.00 |
| $100\sigma_\tau$ | 0.4547 | 0.4174 | 0.4951 | IG | 2.00 | 2.00 |
| $100\sigma_d$ | 7.6949 | 6.3336 | 9.3354 | IG | 10.00 | 2.00 |
| $100\sigma_{tr}$ | 0.3007 | 0.2750 | 0.3282 | IG | 2.00 | 2.00 |
| $100\sigma_{tp}$ | 2.8511 | 2.6336 | 3.0922 | IG | 1.00 | 1.00 |
| $100\sigma_\mu$ | 0.1774 | 0.1530 | 0.2037 | IG | 1.00 | 1.00 |
| 100π | 0.4631 | 0.3955 | 0.5369 | G | 0.5 | 0.05 |
| 100γ | 0.4185 | 0.3523 | 0.4849 | G | 0.4 | 0.05 |
| $.25b^m$ | 0.2672 | 0.2342 | 0.2995 | N | 0.25 | 0.05 |
| g | 1.0865 | 1.0779 | 1.0960 | N | 1.06 | 0.04 |
| $.25\tau$ | 0.0430 | 0.0417 | 0.0445 | N | 0.045 | 0.0025 |

Table 2: Posterior means, 90% posterior error bands and priors of the model parameters. For the structural parameters, M stands for the monetary-led regime, and F stands for the fiscally-led regime. The letters in the column "Type" indicate the prior density function: N, G, B, D, and IG stand for Normal, Gamma, Beta, Dirichlet, and Inverse Gamma, respectively.

4.1 Parameter estimates

Table 2 reports priors and posterior parameter estimates. The priors for the parameters that do not move across regimes are in line with previous contributions in the literature and are relatively loose. As for the parameters of the Taylor rule, the prior for the autoregressive component is symmetric across regimes, whereas we have chosen asymmetric and truncated priors for the responses to inflation and the output gap in line with the theoretical restrictions outlined above: Under the monetary-led regime (M) monetary policy is active, whereas under the fiscally-led regime (F), monetary policy is passive. In a similar way, the priors for the response of taxes to government debt are asymmetric across the two regimes: Under the fiscally-led regime and the ZLB regime, this parameter is restricted to zero, whereas under the monetary-led regime it is expected to be fairly large. In order to separate the short- and long-term components of transfers, we restrict the persistence of the long-term component ($\rho_{eL} = .99$) and the standard deviation of its innovations ($\sigma_{eL} = .1\%$). We fix the discount factor β to .9985, a value broadly consistent with an annualized 2% real interest rate, and the average maturity to 5 years (this is controlled by the parameter ρ). We assume that the persistence of the fiscal rule at the ZLB coincides with its value in the fiscally-led regime: $\rho_{\tau,Z} = \rho_{\tau,F}$.

We choose priors for the persistence of the policy regimes in line with the persistence of the two regimes implied by the regime sequence recovered when estimating the MS-VAR. Finally, we choose a loose and symmetric prior for the parameter p_{ZM} , which captures the uncertainty about the policy that will be carried out after the liftoff of the interest rate from the ZLB. Our symmetric and broad prior implies that we maintain an agnostic view with respect to which exit strategy agents regard as most likely.

Regarding the parameters of the Taylor rule, under the monetary-led regime the federal funds rate reacts strongly to both inflation and the output gap. The opposite occurs under the fiscally-led regime. Under the fiscally-led and ZLB regimes the response of taxes to debt is restricted to zero, while under the

2008:Q1 and 2009:Q3 as possible starting dates. The results of this exercise, the dataset, and evidence for convergence of the MCMC algorithm can be found in Appendix C.

monetary-led regime it turns out to be significantly larger than the threshold value described in Subsection 3.2 ($\beta^{-1} - 1 = .0015$).

Since we fixed the regime sequence, the estimates of the transition matrix are determined by the model dynamics across the different regimes and not by the frequency of regime changes. Both the monetary-led regime and the fiscally-led regime turn out to be quite persistent, implying that when one of the two regimes is in place, agents expect to spend a significant amount of time under such a regime. The persistence of the high state for the discrete preference shock is also very high. This implies that when out of the ZLB, agents attach a small weight to the possibility of a large contraction in real activity deriving from the negative preference shock. This result is consistent with the fact that before the recent crisis, the US economy had always been able to avoid the ZLB. When at the ZLB, agents regard it as more likely that once the negative preference shock is reabsorbed, policymakers will move to the monetary-led regime ($p_{ZM} = 92\%$ at the posterior mean). However, this probability is smaller than the estimated persistence of the monetary-led regime (p_{MM} is around 99%). Therefore, when the economy entered the ZLB, the probability attached to switching to the fiscally-led regime increased and agents' uncertainty about the future policy mix rose.

It is worth clarifying the importance of estimating the model over the whole sample, as opposed to focusing exclusively on the zero-lower-bound period. For the sake of argument, we can think that the properties of the fiscally-led regime are mostly identified by the study of the effects of fiscal imbalances during the 1960s and 1970s.¹⁰ Similarly, the properties of the monetary-led regime are mostly pinned down by the behavior of the economy during the post-Volcker disinflation period. As we shall explain in greater detail in Section 6, for given properties of the monetary-led and fiscally-led regimes, the parameter p_{ZM} highly influences the effects of fiscal imbalances on the macroeconomy at the ZLB. Thus, this key parameter is identified by the joint dynamics of fiscal variables, inflation, and real activity during the ZLB period.

¹⁰The discussion here is simplified to the extent that the properties of one regime depend in part on the properties of the other regimes. Furthermore, there are feedback effects from the macroeconomy to the fiscal variables.

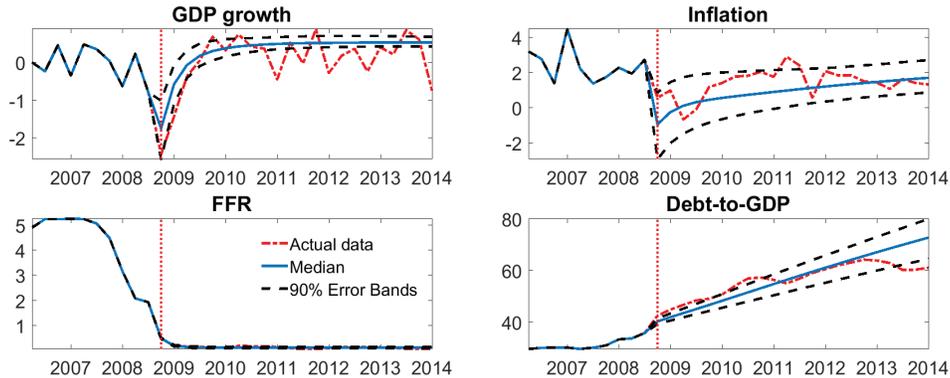


Figure 5: **Macroeconomic dynamics at the zero lower bound.** Response of GDP growth, inflation, FFR, and debt-to-GDP ratio to a discrete negative preference shock. The red dashed line reports actual data.

4.2 Dynamics at the zero lower bound

Figure 5 reports the estimated impulse response to a discrete negative preference shock \bar{d}_t . To compute the impulse response, we use the actual data in 2008:Q3. The shock occurs in 2008:Q4 and is marked by a vertical line.¹¹ The model is able to replicate the key changes that occurred starting with the 2008 crisis as a result of the single discrete negative preference shock, in line with the VAR evidence. The economy experiences a drop in real activity and a large increase in the debt ratio, monetary policy enters the ZLB, but inflation remains relatively stable. It is also interesting to notice that the model is able not only to replicate the absence of deflation, but also the fact that inflation has been trending up. The model rationalizes this behavior as a result of increasing inflationary pressure coming from the large debt accumulation.

The absence of deflation is tightly linked to uncertainty about policymakers' future behavior. To show this, Figure 6 compares the effects of the discrete negative preference shock under the benchmark estimated model with its effects in a counterfactual economy in which the monetary-led policy mix is the only possible regime when out of the ZLB (dashed line). Thus the vertical distance

¹¹Using actual data is important because the impulse response is not invariant with respect to the state of the economy, namely the observed fiscal imbalances. This is because the negative preference shock affects agents' beliefs about policymakers' future behavior.

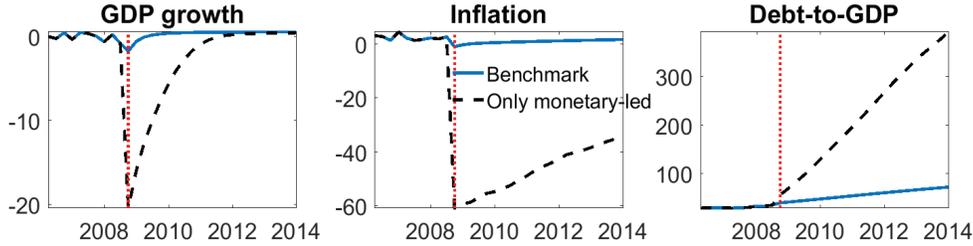


Figure 6: **Actual and counterfactual impulse responses to a discrete negative preference shock.** The solid blue line corresponds to the estimated model, whereas the black dashed line corresponds to a counterfactual economy in which the monetary-led policy mix is the only possible policy mix.

between the two lines captures the effects of uncertainty about the exit strategy on the output gap, inflation, and the debt-to-GDP ratio. Notice that under the counterfactual economy, the negative preference shock has now a much larger impact on inflation and real activity. The economy experiences a very large and persistent deflation and a much larger contraction in output. Furthermore, the massive increase in the debt-to-GDP ratio does not have any mitigating effect on inflation: Agents expect that the entire debt-to-GDP ratio will eventually be repaid with an increase in taxation. Thus, paradoxically, the uncertainty about future policy was beneficial, rather than harmful, to macroeconomic performance. This does not mean that policy uncertainty is beneficial in itself, but it implies that when monetary policy becomes constrained by the ZLB, the resulting policy uncertainty mitigates the consequences of the ZLB by creating inflationary pressure.

Note that in the counterfactual economy the contraction in output and the drop in inflation are unrealistically large because we are removing the key mechanism of the estimated model. In Section 5, we will formally compare our benchmark model to an estimated nested model that removes policy uncertainty in a way that puts the two models on the same ground. The goal in this section is instead to isolate the key mechanism that prevents deflation in the estimated model. In this respect, the fact that the model can in principle reproduce the standard features of the ZLB is important: The data could have rejected the role played by policy uncertainty in explaining inflation dynamics. For example, the estimates could have suggested a very small probability of ever moving to

the fiscally-led regime and a counteracting mark-up shock that keeps inflation positive. Instead, a large preference shock is found to explain the sharp decline in real activity. The absence of deflation is then rationalized in light of the possibility of a change in the monetary/fiscal policy mix.¹²

It is also important to emphasize that the amount of policy uncertainty required to explain the absence of deflation during the Great Recession is quite moderate. As shown in Table 2, the posterior mean of the probability of moving to the monetary-led policy mix once out of the ZLB regime is $p_{ZM} = 92.25\%$. This implies that at the ZLB agents mostly believe that policymakers will eventually resume the same policy mix observed before the Great Recession. Such a belief is plausible for the US in light of the long spell of monetary-led policy mix observed between the Volcker disinflation and the onset of the Great Recession. However, as noted earlier, this value implies a higher probability of moving to the fiscally-led regime than that in the pre-crisis period. Finally, in the estimated model, the magnitude of the inflationary effects of uncertainty about the exit strategy largely depend on the pre-crisis level of government debt, which is observed to be above its estimated steady-state value (around 42.5%).

Figure 7 provides further corroborating evidence in favor of the mechanism proposed in this paper. The figure reports the evolution of the one-year-ahead and five-year-ahead inflation expectations as implied by the model and compares them with the Michigan surveys. The error bands reflect parameter uncertainty. Even though we do not use inflation expectations for estimation, the model is able to replicate the salient features of the Michigan surveys. First, the model captures the upward trend in inflation expectations that is visible right before the recession started. This pattern can be partially explained by the increase in the US fiscal burden during those years. Second, the model captures remarkably well the swing in inflation expectations that occurred once the crisis started. From above trend, inflation expectations quickly moved below trend. However, they never became negative and they quickly recovered. Finally, at the ZLB inflation expectations exhibit an upward trend. The model explains this pattern

¹²In Appendix D we show that our results do not depend on the shock that triggers the zero lower bound. To that end, we consider a prototypical New Keynesian model in which we can directly shock the natural rate as in Eggertsson and Woodford (2003).

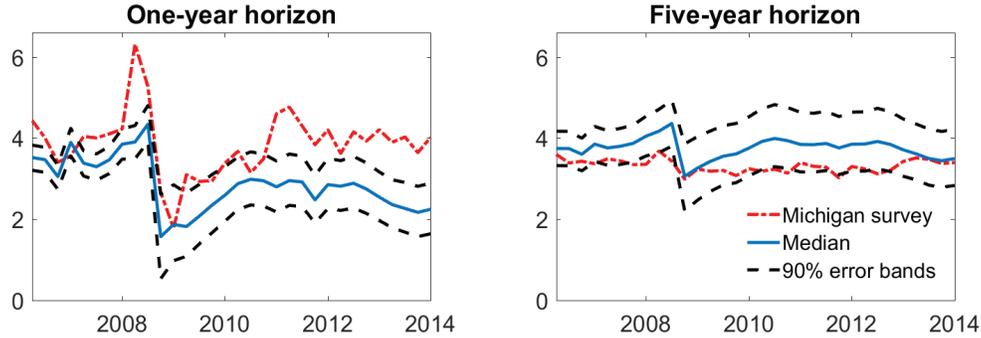


Figure 7: **Inflation expectations.** The figure reports the evolution of the model-implied one-year-ahead and five-year-ahead inflation expectations together with the Michigan surveys (red dashed dotted line).

as a result of the large debt accumulation.

We find it reassuring that the model is able to replicate these key facts even if inflation expectations are not used for estimating the model. This result shows that the inflationary pressure coming from the fiscal burden delivers inflation expectations that are very much in line with the data. It is important to emphasize that inflation expectations moved down, as predicted by our model, when the ZLB was encountered, but they never entered negative territory. In other words, agents were confident that deflation would not have occurred. Instead, in the baseline New Keynesian model, where the monetary-led policy mix is the only possible regime, agents should expect deflation once the economy enters the ZLB. The fact that inflation expectations, and not just inflation, behave in a way that is not consistent with the baseline New Keynesian model suggests that the absence of deflation in the United States cannot be easily rationalized ex-post with a series of lucky realizations of inflationary shocks.

4.3 Inspecting the fiscal mechanism

In our model, how shocks propagate depends on the policy regime in place as well as the state variables of the economy. This property is key for the model to rationalize the absence of deflation at the ZLB. Figure 8 reports the impulse responses to an increase in the long-term component of transfers under the three different regimes. This shock has a direct impact on the debt-to-GDP ratio

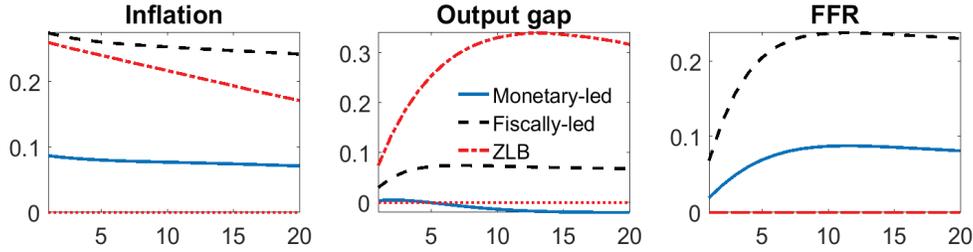


Figure 8: **Impulse responses to a shock to transfers.** The impulse responses are computed assuming a regime in place over the the relevant horizon. However, agents form expectations taking into account the possibility of regime changes.

and, consequently, on the amount of spending that would have to be financed with future taxes. Impulse responses are computed conditionally on each policy 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 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 that adjusts the interest rate less than one-to-one to inflation. The resulting decline in the real interest rate 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 GDP growth.

Under the monetary-led regime the primary deficit shock triggers a much smaller increase in inflation because the fiscal authority is expected to implement the necessary fiscal adjustments. However, the response of inflation is not zero because agents form expectations taking into account the small possibility of moving to the fiscally-led regime. As a result, a high level of spending determines some inflationary pressure even when the monetary-led regime is in place. However, the rise in inflation is moderate compared to the case in which the fiscally-led policy mix is in place. 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 slightly negative output gaps that last as long as the fiscal imbalance is not fully reabsorbed.

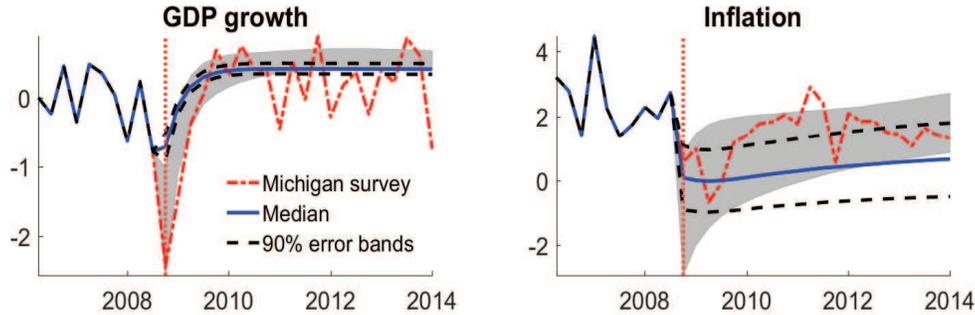


Figure 9: **Macroeconomic dynamics at the zero lower bound for a model without the fiscal block.** Response of GDP growth and inflation to a discrete negative preference shock based on a model that excludes the fiscal block. The red dashed line reports actual data, while the shaded areas report the 90% error bands for the benchmark model.

Under the zero-lower-bound regime the effects of the fiscal shock are quite similar to those that characterize the fiscally-led regime even though the probability to a return to the monetary-led regime (p_{ZM}) is quite large. The increase in spending triggers a large increase in inflation. Given that the FFR is stuck at zero, the resulting drop in the real interest rate is amplified with a consequent large increase in the output gap. However, inflation is slightly smaller than under the fiscally-led policy mix because the faster output growth ends up ameliorating the fiscal imbalance.

5 No Policy Uncertainty

In the previous section, we used a counterfactual simulation to isolate the role of policy uncertainty in accounting for the absence of deflation. In such an exercise, since it is a counterfactual simulation, all shocks and non-policy parameters of the model are kept fixed. In this section, we go one step further and formally compare the benchmark model with an estimated nested model that does not feature policy uncertainty about the way debt will be stabilized. Given that both models are now estimated, we can conduct a formal assessment of the role played by the fiscal block in explaining the joint dynamics of GDP and inflation as well as inflation expectations at the ZLB.

The nested model is similar to the traditional New Keynesian model used by

| Benchmark Model | | | | | |
|----------------------------|---------------|--------|--------|--------|--------|
| Variable | <i>Median</i> | 5% | 95% | 16% | 84% |
| GDP growth | 0.2997 | 0.2324 | 0.4172 | 0.2552 | 0.3595 |
| Inflation | 0.0638 | 0.0312 | 0.1897 | 0.0351 | 0.1338 |
| Model without Fiscal Block | | | | | |
| Variable | <i>Median</i> | 5% | 95% | 16% | 84% |
| GDP growth | 0.4134 | 0.3607 | 0.4723 | 0.3807 | 0.4485 |
| Inflation | 0.1042 | 0.0331 | 0.3075 | 0.0461 | 0.2066 |

Table 3: Mean squared distance between the actual data and the path implied by the discrete preference shock. The top panel refers to the benchmark model, and the lower panel refers to a nested New Keynesian model that excludes the fiscal block. The period considered is 2008:Q4-2014:Q1.

Clarida et al. (2000) and Lubik and Schorfheide (2004) and it does not feature any uncertainty about the way debt will be financed. We still allow for the possibility of changes in policymakers' behavior, but now such changes only concern the behavior of the monetary authority. As observables, we use four of the seven series used to estimate the benchmark model: GDP growth, inflation, federal funds rate, and government expenditure.¹³ Figure 9 reports the impulse responses to the discrete negative preference shock based on this alternative model. The figure is analogous to Figure 5 shown above for the benchmark model. To ease the comparison, the shaded areas report the bands for the benchmark model. As before, we use the actual data until 2008:Q3 and we then have the discrete shock occurring in 2008:Q4. Unlike the benchmark model, the model without the fiscal block is not able to account for the joint dynamics of inflation and output growth as a result of the single discrete preference shock. The model is able to track relatively well the behavior of inflation, even if inflation is often outside the 90% error bands. On the other hand, it clearly misses the magnitude of the contraction in growth.

To formalize this visual impression, Table 3 reports the mean squared distance between the actual data and the path in response to the discrete demand shock implied by the two models. The benchmark model delivers better results both for inflation and output growth. However, in line with what could already

¹³Including the remaining fiscal series would be irrelevant for the dynamics of the macroeconomy because Ricardian equivalence applies when assuming that fiscal policy is always passive. Details about the model and the parameter estimates can be found in Appendix E.

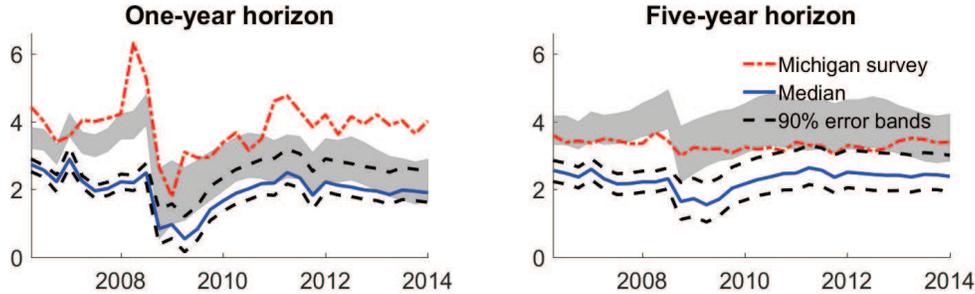


Figure 10: **Inflation expectations for a model without the fiscal block.** The figure reports the evolution of the one-year-ahead and five-year-ahead inflation expectations implied by a model that excludes the fiscal block. The red dashed lines correspond to the Michigan surveys inflation expectations. The shaded areas report the 90% error bands for the benchmark model.

be inferred by the picture, the gains are particularly large for output growth. Not only is the median of the mean squared distance significantly smaller, but also the 68% bands do not overlap. As shown in Appendix E, the model without the fiscal block uses the discrete shock to fit inflation dynamics, leaving the behavior of output to be explained by a contemporaneous TFP shock. Therefore, when excluding the fiscal block we obtain the standard result of the literature: A combination of shocks is necessary in order to explain the joint dynamics of inflation and output following the recent recession.

As further evidence in favor of the mechanism proposed in this paper, Figure 10 reports the evolution of inflation expectations implied by the model without the fiscal block. Once again, we use shaded areas to denote the 90% error bands for the benchmark model. Even in this case, we find that the alternative model performs worse than the benchmark model. The model without a fiscal block tends to constantly underestimate inflation expectations, which lie outside the 90% error bands most of the time. This is true for both the one-year-ahead and the five-year-ahead expectations. Furthermore, the alternative model does worse both before and after the economy entered the ZLB.

Table 4 formally compares the two models with respect to their ability to replicate the dynamics of inflation expectations. For each model, we compute the mean squared distance between the model-implied inflation expectations and the actual inflation expectations. It is important to check that the im-

| Benchmark Model | | | | | |
|----------------------------|---------------|--------|--------|--------|--------|
| Variable | <i>Median</i> | 5% | 95% | 16% | 84% |
| Whole sample: 1-year | 0.0569 | 0.0374 | 0.0857 | 0.0440 | 0.0733 |
| Whole sample: 5-year | 0.0451 | 0.0345 | 0.0641 | 0.0378 | 0.0557 |
| Pre-ZLB: 1-year | 0.0424 | 0.0317 | 0.0615 | 0.0349 | 0.0529 |
| Pre-ZLB: 5-year | 0.0493 | 0.0383 | 0.0734 | 0.0415 | 0.0625 |
| Post-ZLB: 1-year | 0.1001 | 0.0368 | 0.2067 | 0.0551 | 0.1595 |
| Post-ZLB: 5-year | 0.0181 | 0.0037 | 0.0958 | 0.0066 | 0.0532 |
| Model without Fiscal Block | | | | | |
| Variable | <i>Median</i> | 5% | 95% | 16% | 84% |
| Whole sample: 1-year | 0.1675 | 0.1399 | 0.1955 | 0.1510 | 0.1840 |
| Whole sample: 5-year | 0.1563 | 0.1106 | 0.2141 | 0.1307 | 0.1894 |
| Pre-ZLB: 1-year | 0.1496 | 0.1241 | 0.1880 | 0.1349 | 0.1696 |
| Pre-ZLB: 5-year | 0.1836 | 0.1281 | 0.2557 | 0.1510 | 0.2229 |
| Post-ZLB: 1-year | 0.2309 | 0.1005 | 0.3008 | 0.1577 | 0.2778 |
| Post-ZLB: 5-year | 0.0656 | 0.0139 | 0.1369 | 0.0298 | 0.1058 |

Table 4: Mean squared distance between model-implied and actual inflation expectations for the 1-year and 5-year horizons. The top panel refers to the benchmark model, and the lower panel refers to a nested New Keynesian model that excludes the fiscal block. We report results for the whole sample for which expectations are available (1978:Q1-2014:Q1), for the subsample before the economy entered the zero lower bound (1978:Q1-2008:Q3), and for the subsample after the economy entered the zero lower bound (1978:Q4-2014:Q4).

provement in the ability to match the behavior of inflation expectations does not occur only at the ZLB, because this could be just a lucky coincidence. We therefore take the mean squared distance over the whole sample for which inflation expectations are available (1978:Q1-2014:Q1) and for two subsamples: before and after entering the ZLB. The benchmark model performs better than the alternative model over all subsamples and for both horizons.

6 Policy Trade-off

In this section, we are interested in assessing why policy uncertainty is likely to increase once the economy enters the ZLB. We will show that while the monetary-led regime leads to a more stable macroeconomic environment during regular times, a policy trade-off characterizes the ZLB: mitigating a large recession or preserving long-run macroeconomic stability. Policy uncertainty rises when policymakers do not offer a clear resolution of this policy trade-off.

Let us revisit the effects of the large negative preference shock \bar{d}_t under three different scenarios concerning policymakers' behavior. In the first scenario, we consider the benchmark model in which no announcement is made. In the second and third scenarios policymakers make credible announcements about the exit strategy. Specifically, in the second scenario, policymakers announce that fiscal discipline will be abandoned and that the economy will move to the fiscally-led regime. In the third scenario, policymakers announce that once the economy is out of the zero-lower-bound period, fiscal discipline will be restored, implying that the economy will move back to the monetary-led regime.¹⁴

Figure 11 reports the results. If policymakers announce that fiscal discipline will be abandoned (dashed line), agents expect that the rising stock of debt 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 and the economy is effectively avoiding the ZLB. If instead policymakers explicitly announce fiscal discipline, the economy enters a recession and deflation arises (dashed-dotted line). Compared to the case in which no announcement is made (solid line), announcing fiscal discipline worsens the recession and brings about a larger drop in prices. This is because this announcement lowers the probability that the growing stock of debt will be inflated away, which raises the real interest rate and consequently leads to a recession deeper than the one we actually observed. The outcomes for this case are qualitatively in line with the traditional view about the ZLB. However, the drops in real activity and inflation are substantially mitigated compared to the counterfactual economy presented in Subsection 4.2, in which the monetary-led policy mix is the only possible regime. The reason is that when policymakers announce fiscal discipline, rational agents understand that a switch to the fiscally-led regime can still occur in the more distant future.

Figure 12 illustrates the evolution of uncertainty for the three scenarios presented above. We consider three horizons: 1 quarter, 1 year, and 2 years. Uncertainty is computed taking into account the possibility of regime changes and future Gaussian shocks (Bianchi 2016). For a variable X_t and a horizon q ,

¹⁴Appendix B.3 presents the transition matrix for the economy with announcements.

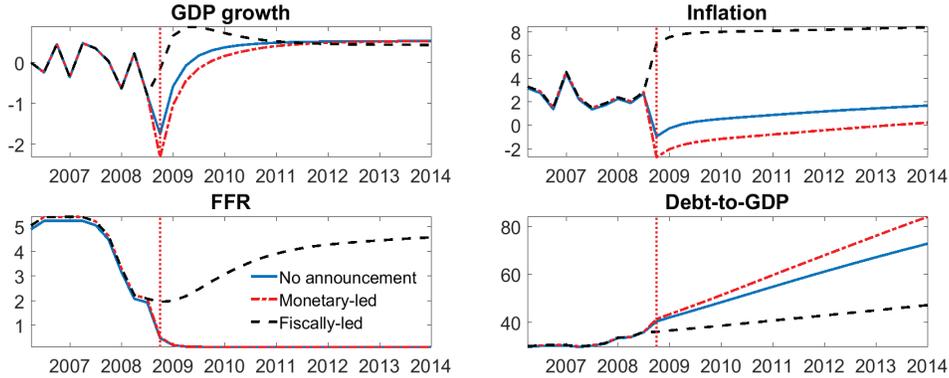


Figure 11: **Effects of policy announcements following the discrete negative preference shock.** Three cases are considered. The first case corresponds to the benchmark model with no announcement; in the second case, policymakers announce a return to the monetary-led regime; in the third case, a switch to the fiscally-led regime is announced.

it corresponds to the conditional standard deviation $sd_t(X_{t+q})$. At the ZLB, uncertainty is higher than in the pre-crisis period because of the uncertainty about the end of the recession and the lack of a systematic monetary policy response to shocks hitting the macroeconomy. When policymakers announce the fiscally-led regime as the exit strategy, the economy avoids hitting the ZLB and consequently macroeconomic uncertainty remains very close to the pre-crisis levels. Hence, promising to follow the fiscally-led policy mix has the effects of mitigating the recession and of lowering macroeconomic uncertainty in the short run.

Longstaff et al. (2013), following Kitsul and Wright (2013), extract the objective distribution of inflation from the market prices of inflation swaps and options by using data at daily frequency. They find substantial swings between fears of inflation and fears of deflation. Such a large level of uncertainty about inflation is consistent with our findings. We regard the study of the link between policy uncertainty and macroeconomic uncertainty in the context of asset pricing as an interesting and promising venue for future research.

The measure of uncertainty reported here reflects the level of uncertainty faced by the agent in the model, taking into account the possibility of regime changes, along the simulations presented above. Therefore, they cannot be immediately compared with measures of uncertainty based on reduced-form sta-

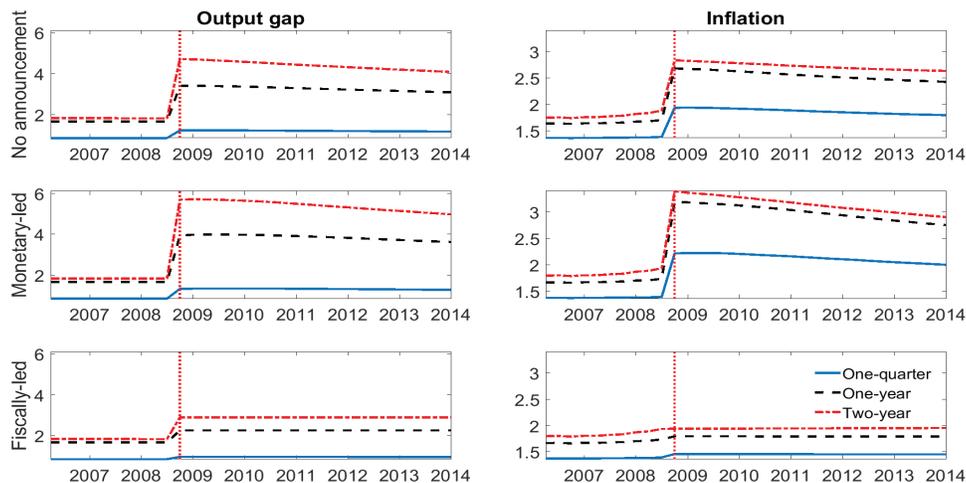


Figure 12: **Evolution of uncertainty under policy announcements.** The graphs report the evolution of uncertainty at different horizons following an adverse discrete preference shock and different announcements about policymakers’ future behavior.

tistical models such as the ones presented by Jurado et al. (2015). If we were to estimate a reduced-form model with time-varying parameters and heteroskedasticity on the economy simulated above, we would find that uncertainty spikes when the economy enters the ZLB. Nevertheless, uncertainty would stay low while the economy remains at the ZLB because no large changes in real activity or inflation occur.¹⁵ Such a measure of uncertainty would be in line with the evidence presented in Jurado et al. (2015). Therefore, our results should be interpreted as showing that the ZLB implies an increase in uncertainty for a given level of volatility of the exogenous shocks.

While moving to the fiscally-led regime would largely mitigate the recession and reduce uncertainty in the short run, it would also imply an increase in macroeconomic uncertainty in the long run. Figure 13 reports the evolution of uncertainty at different horizons, from 1 quarter to 10 years, when the monetary-led and the fiscally-led regime are in place. 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,

¹⁵See Justiniano and Primiceri (2008), Bianchi (2013), Fernandez-Villaverde et al. (2010), and Bianchi and Ilut (2015) for examples of DSGE models that allow for heteroskedasticity.

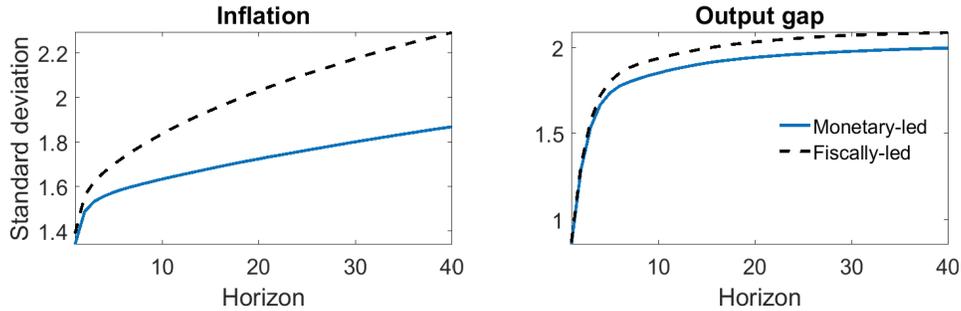


Figure 13: **Evolution of uncertainty when out of the zero lower bound.** Evolution of uncertainty at different horizons conditional on being in a specific regime today, taking into account the possibility of future regime changes.

the central bank responds strongly to inflation, leading to a further reduction in volatility. If instead policymakers follow the fiscally-led regime, uncertainty increases at all horizons. This is because the central bank reacts less aggressively to economic fluctuations and agents anticipate that all fiscal imbalances will now strongly affect inflation and real economic activity.

Mitigating a large recession by pledging to abandon fiscal discipline and the rise in uncertainty as the economy exits the ZLB are two sides of the same coin. The announcement effectively softens 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 do agents expect that debt will be inflated away. If the fiscally-led regime had low persistence, the announcement would fail to mitigate the recession because inflation would not rise. In fact, agents would simply expect a change in the timing of fiscal adjustments. The existence of this trade-off between short-run benefits and long-run costs provides an explanation for the ample spectrum of opinions about the best path of action at the zero lower bound and the consequent increase in policy uncertainty.

7 Conclusions

The US is arguably facing uncertainty about the way policymakers will handle the large stock of debt that was accumulated during the Great Recession. Part of the debt is expected to be absorbed by higher growth once the economy fully

recovers. However, it is quite unlikely that this factor alone will be enough to correct the dynamics of US sovereign debt in the absence of substantial fiscal adjustments. A large stock of debt, combined with no clear plan for fiscal stabilization, is likely to create uncertainty about the future policy course because the monetary authority cannot control inflation without the necessary fiscal backing (Sims 2010a). We have shown that this type of policy uncertainty can explain why the US economy has not experienced deflation despite the several years spent at the zero lower bound.

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Working Paper Series *(continued)*

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Working Paper Series *(continued)*

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|--|-----------------|
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Working Paper Series *(continued)*

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|--|-----------------|
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