

Dormant Shocks and Fiscal Virtue*

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PRELIMINARY, COMMENTS WELCOME

Abstract

We develop a model in which the current behavior of the fiscal and monetary authorities influence agents' beliefs about the way debt will be stabilized. The standard policy mix consists of a virtuous fiscal authority that moves taxes in response to debt and a Central Bank that has full control over inflation. When policy makers deviate from this virtuous policy mix, agents conduct Bayesian learning to infer the likely duration of the deviation. As agents observe more and more deviations, they become increasingly pessimistic about a prompt return to the virtuous regime and inflation starts moving to keep debt on a stable path. Shocks which were *dormant* under the virtuous policy mix start now manifesting themselves. These changes are initially imperceptible, but they unfold over decades and accelerate as agents get convinced that the fiscal authority will not raise taxes. Dormant fiscal shocks can account for the run-up of inflation in the '70s and the deflationary pressure of the early 2000s. We point out that the currently low long term interest rates and inflation expectations might hide the true risk of inflation faced by the US economy.

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1 Introduction

The importance of modeling the interaction between fiscal and monetary policies goes back to the seminal contribution of Sargent and Wallace (1981). However, in many of the models that are routinely used to investigate the sources of macroeconomic fluctuations fiscal policy plays only a marginal role. The vast majority of papers resolve the problem of the monetary/fiscal policy coordination assuming that the fiscal authority stands ready to accommodate the behavior of the monetary authority, keeping the process for debt on a stable path. This is a strong assumption as a casual observation of the data shows that countries often experience prolonged periods of severe fiscal imbalance. Quite interestingly, these episodes are frequently followed by significant increases in inflation. In some cases, such increases are short lasting and remarkably violent. In other cases, they unfold over many years, generally starting with small increases and then gaining momentum. In this respect, an interesting case is represented by the US Great Inflation of the '70s. Inflation started increasing in the mid-60s, gained momentum in the early '70s, and got out of control towards the end of that same decade. Traditional models have a hard time in endogenously generating persistent and accelerating increases in inflation and in explaining the cross-country heterogeneity characterizing the link between inflation and fiscal discipline. In this paper we show that a model in which fully rational agents are uncertain about the future conduct of monetary and fiscal policies can account for these two features.

We model an economy populated by a continuum of agents that are fully rational and understand that debt can be stabilized through movements in taxes or movements in inflation. When the fiscal authority is virtuous and moves taxes in response to fluctuations in the debt-to-GDP ratio, the Central Bank has full control over inflation. Under the assumption of non-distortionary taxation, fiscal shocks do not have any effect on the real economy as they only redistribute the timing of taxation. When policy makers deviate from this virtuous rule, two situations can arise. If agents expect the return to the virtuous regime to be close enough in time, inflation stability is preserved. However, if the deviation is expected to last for a long period of time, high levels of debt require an increase in inflation.¹

We build over this basic intuition and assume that when facing a deviation from the virtuous rule, agents do not know how long it will take to move back. Instead, they have to conduct Bayesian learning to infer the nature of the deviation. As they observe more and more deviations, they get increasingly convinced that a prompt return to the virtuous regime is very unlikely. Given that agents are fully rational and understand that debt has to be

¹We consider non-distortionary taxation to isolate the effects related to fiscal virtue. The mechanism described in this paper would still be at work in a model with distortionary taxation.

financed in one way or the other, the drift in agents' beliefs determines a progressive increase in inflation. The initial movement can be almost undetectable, but as initially optimistic agents become relatively pessimistic, inflation accelerates, gaining momentum and getting out of control. At the same time, expected and realized volatilities go up as shocks that are *dormant* under the virtuous regime slowly start manifesting themselves. Therefore, an external observer that were monitoring the economy focusing exclusively on output and inflation would detect a run-up in inflation and an increase in volatility without any apparent reason. The observer might then conclude that the volatility of the exogenous shocks and the target for inflation have both increased.

Dormant shocks are undetectable when policy makers are virtuous or agents are optimistic that they will be virtuous in the future because agents understand that any imbalance in the debt-to-GDP ratio will be followed by an adjustment in taxation. As agents get discouraged about the future behavior of policy makers, the effects of dormant shocks arise. Therefore, dormant shocks can have effects many years after they occurred, as long as the imbalance in the debt-to-GDP ratio that they generated is not totally reabsorbed by the time the deviation from the virtuous regime occurs. Furthermore, even after a regime change, their effects can be barely detectable if agents find extremely unlikely that policy makers will engage in a long lasting deviation from the virtuous regime. In other words, depending on policy makers' *fiscal virtue*, inflation can stay low for many periods, as it takes time for agents to get convinced that the economy entered a long lasting deviation. According to the same logic, if on average policy makers spend a lot of time in the virtuous regime, agents might become more tolerant when observing a long sequence of deviations. However, no matter how optimistic agents are or how virtuous policy makers have been in the past, if a deviation lasts for an extended period of time, agents will eventually get convinced that a quick return to the virtuous regime is unlikely. In other words, following a deviation, fiscal virtue can delay the effects of dormant shocks, but it cannot eliminate them.

The interaction between dormant shocks and fiscal virtue also provides an appealing explanation for why countries with different levels of debt might have similar levels of inflation for prolonged periods of time, but then experience very different outcomes during *hard times*. When a virtuous regime prevails or agents are confident that it will prevail in the future, the level of debt is substantially irrelevant. However, if agents get convinced that the economy entered a long lasting deviation, then interest rate and inflation differentials open up. The larger the difference in fiscal virtue, the larger the difference in the speed of learning, the faster the opening of the inflation and interest rate differentials.

Given that the underlying mechanism relies on uncertainty around the source of financing for the debt-to-GDP ratio, all shocks that move this variable are potential candidates

to be dormant shocks. In an environment with no distortionary taxation, shocks to transfers and taxes are particularly interesting, given that they do not have *any* effect on the macroeconomic variables when the virtuous regime is in place, while they can generate large fluctuations in inflation once policy makers start deviating. Furthermore, given that agents are forward looking, even announced changes in expenditure and/or taxation would trigger the inflationary mechanism.

We calibrate the model using the estimates obtained in Bianchi and Ilut (2011) and we show that the presence of dormant shocks can explain some important stylized facts regarding the evolution of inflation. First, the entire run-up of inflation of the '70s can be obtained considering only two shocks. The first spur of inflation, would be the result of the *announcement* of the Great Society initiatives of president Lyndon Johnson around 1964, while the second acceleration would be caused by Ford's tax cuts. The progressive deterioration of agents' beliefs explains why inflation seemed to gain momentum over time. Second, as in Bianchi and Ilut (2011), the sudden drop in inflation of the early '80s can be explained by a sudden switch in the monetary/fiscal policy mix induced by the appointment of Volcker. Finally, if we assume that even under the virtuous regime agents are concerned about the possibility of a jump to the long lasting inflationary policy mix, we can account for the risk of deflation of the early 2000s as a result of the large primary surpluses of the '90s.

Finally, we use the model to make a series of considerations regarding the current situation. First, given that dormant shocks might take a long time to unfold, we should not interpret the current low levels of inflation expectations and the long term interest rates as reflecting a low risk of high inflation for the US economy. We show that if US policy makers were to follow the current policy mix for a prolonged period of time, inflation might quickly accelerate and get out of control. Second, we analyze the role of agents' expectations about the exit strategy in determining the effects of current policies, with a special focus on the choice of keeping interest rates at zero for a prolonged period of time. If agents believe that these exceptional measures will be followed by a return to a virtuous regime, then inflation and output do not move. On the other hand, if US policy makers were to *explicitly* announce that at least part of the current stock of debt will not be covered by an increase in taxes, then inflation would increase quickly, lowering real interest rates and boosting the economy. Finally, we show that a lack of coordination in the announcement made by the fiscal and monetary authorities could have perverse consequences if agents were to interpret it as signal of a likely conflict between the two authorities.

The role of fiscal policy in explaining the rise in inflation in the '70s has been studied by Sims (2009), Cochrane (1998, 2001), and, more recently, by Bianchi and Ilut (2011).

Cochrane (1998, 2001) takes a *frictionless* and model free approach, solving the government budget constraint forward and treating the price level as the variable that is free to move in order to keep the real value of debt in line with the present value of future real surpluses. Bianchi and Ilut (2011) consider a DSGE model subject to a structural break in the monetary/fiscal policy mix, while Sims (2009) relies on VAR and DSGE analysis. All of these papers contain elements of the Fiscal Theory of Price Level, developed by Leeper (1991), Sims (1994), Woodford (1994), and Woodford (1995).² We build on the results of this literature, introducing Bayesian learning in a general equilibrium model in which agents are fully aware of the trade-off between inflation and taxation. This has the important effect of creating a continuum of regimes indexed according to agents' beliefs. Therefore, in our model the strict distinction between Ricardian and non-Ricardian regimes typical of the Fiscal Theory Price Level literature breaks down and is replaced by a series of intermediate regimes that reflect agents' expectations about the future conduct of fiscal and monetary policies. Consequently, the economy experiences a smooth transition from the law of motion that prevails under the virtuous regime to the one that characterizes a long lasting deviation.

Furthermore, agents in our model *know that they do not know*. Therefore, when forming expectations, they take into account that their beliefs will evolve according to what they observe. In this dimension, our approach is clearly different from the one used in the traditional learning literature that assumes anticipated utility, i.e. that agents form expectations conditional on their beliefs without taking into account that these are likely to change in the future. In our context, it is possible to go beyond the anticipated utility assumption because there is only a finite number of relevant beliefs and they are strictly linked to the behavior of policy makers through the learning mechanism, in a way that we can keep track of their evolution.

In this respect, our paper is related to Eusepi and Preston (2011), who study the problem of macroeconomic stability in a model in which agents use adaptive learning to make forecasts about the future evolution of fiscal and monetary variables. In their model, if agents were fully rational, fiscal policy and the maturity structure of debt would be irrelevant because the Taylor Principle holds and fiscal policy is Ricardian. When agents do not know the parameters of the true model, Ricardian equivalence may fail to hold. The important difference with our paper is that the model of Eusepi and Preston (2011) does not feature the mechanism of inflation formation proposed by the fiscal theory of price level which can only arise in models with fully rational agents. In their context, non-Ricardian equivalence arises

²See Cochrane (2011) for an effective discussion of the difference between the early approach of Sargent and Wallace (1981) and the subsequent analysis based on the Fiscal Theory of Price Level. See Atkeson et al. (2009) for an alternative approach to price determination in monetary general equilibrium models.

because agents might erroneously regard bonds as net-wealth as in Barro (1974). Instead, in this paper non-Ricardian equivalence arises because agents understand that debt can be kept stable by movements in inflation or movements in taxation.

To the extent that the paper provides a theory for the movements in trend inflation, our work is also related to Cogley et al. (2008), Benati (2008), Cogley et al. (2011), and Coibion and Gorodichenko (2011). Cogley et al. (2008) study changes in the persistence of the inflation gap measured in terms of short- to medium-term predictability. Coibion and Gorodichenko (2011) point out that the determinacy region in a model with positive trend inflation could be smaller than what implied by the Taylor principle. They conclude that the US economy was still at risk of indeterminacy in the '70s, even if the Taylor principle was likely to be satisfied, because of the high level of trend inflation. In this paper, the learning mechanism generates a persistent increase in inflation that an external observer would interpret as an increase in the target. Our work is also related to Primiceri (2006), Cogley and Sargent (2005), and Sargent et al. (2006). These authors explain the events of the '70 with models in which the beliefs of the monetary authority around the structure of the economy are evolving over time.

In line with Cochrane (1998, 2001), we recognize the importance of allowing for a maturity structure of government debt. Longer maturities imply important fluctuations in the return of bonds and consequently in the present value of debt and Hall and Sargent (2010) show that these revaluation effects explain a significant fraction of the fluctuations of the debt-to-GDP ratio.

The idea that the monetary/fiscal policy mix can change over time has been explored by Davig and Leeper (2006) and Favero and Monacelli (2005). These authors estimate Markov-switching Taylor and fiscal rules, plugging them into a calibrated DSGE model. Finally, the paper is obviously related to the extensive literature that explores the evolution of output and inflation over the past fifty years. Clarida et al. (2000) and Lubik and Schorfheide (2004) point out that in the '70s the economy was subject to the possibility of self-fulfilling inflationary shocks because of the monetary policy rule that was followed at that time. Fernández-Villaverde and Rubio-Ramírez (2007) and Fernández-Villaverde et al. (2010) consider models with time-varying structural parameters and find substantial evidence of parameter instability. Using a large scale DSGE model augmented with stochastic volatilities, Justiniano and Primiceri (2008) find that investment shocks play a key role in explaining the changes in the reduced form properties of the economy. Davig and Doh (2008) estimate a New-Keynesian model in which structural parameters can change across regimes to assess the sources that lead to a decline in inflation persistence. Bernanke and Mihov (1998), Leeper and Zha (2003), Stock and Watson (2003), Canova and Gambetti (2004),

Kim and Nelson (2004), Cogley and Sargent (2006), and Primiceri (2005) provide little evidence in favor of the view that the monetary policy rule has changed drastically. Finally, Ireland (2007), Liu et al. (2008), and Schorfheide (2005) consider models in which the target for inflation is moving over time.

The content of this paper can be summarized as follows. Section 2 describes the model, outlining its properties under fixed coefficients. Section 3 introduces regime changes and learning. Section 4 introduces the notion of dormant shocks and explains how they are related to fiscal virtue. Section 5 and 6 put the theory at work: First looking at the past, then looking at the future. Section 7 concludes.

2 The Model

We consider a New-Keynesian model augmented with a fiscal block. The model is a simplified version of the one used in Bianchi and Ilut (2011).

Households

The representative household maximizes the following utility function:

$$E_0 \left[\sum_{s=0}^{\infty} \beta^s d_s \left[\log (C_s - \Phi C_{s-1}^A) - h_s \right] \right] \quad (1)$$

subject to the budget constraint:

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

where D_t stands for dividends paid by the firms, C_t is consumption, h_t is hours, W_t is the real wage, T_t stands for taxes, and C_s^A represents the average level of consumption in the economy. The parameter Φ captures the degree of external habit. The preference shock d_s has mean one and time series representation: $\log (d_t) = \rho_d \log (d_{t-1}) + \sigma_d \varepsilon_{d,t}$. Following Eusepi and Preston (2011) and Woodford (2001), we assume that there are two types of government debt: 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 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 asset can be interpreted as a portfolio of infinitely many bonds, with weights along the maturity structure given by $\rho^{T-(t+1)}$. Varying the parameter ρ varies the average maturity of debt.

Firms

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

$$Y_t(j) = (P_t(j)/P_t)^{-1/\nu} Y_t \quad (2)$$

where the parameter $1/\nu$ 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:

$$AC_t(j) = .5\varphi (P_t(j)/P_{t-1}(j) - \Pi_{t-1})^2 Y_t(j) P_t(j)/P_t \quad (3)$$

where Π_{t-1} is the gross inflation rate that prevailed in the previous period.

The firm's problem consists in choosing the price $P_t(j)$ to maximize the present value of future profits:

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

where Q_s is the marginal value of a unit of the consumption good: $Q_s/Q_t = \beta [u_c(s)/u_c(t)]$.

Labor is the only input in a linear production function:

$$Y_t(j) = A_t h_t(j) \quad (4)$$

where total factor productivity A_t evolves according to an exogenous process:

$$\ln A_t = \gamma + \ln A_{t-1} + a_t \quad (5)$$

$$a_t = \rho_a a_{t-1} + \sigma_a \varepsilon_{a,t} \quad (6)$$

Government

The (linearized) total government expenditure as a fraction of GDP is assumed to follow the exogenous process:

$$\tilde{e}_t = \rho_e \tilde{e}_{t-1} + \sigma_{e^L} \epsilon_{e^L,t}$$

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

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

where S_t represents the primary surplus at time t . We rewrite the government budget constraint in terms of debt-to-GDP ratio:

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

where $b_t^m = P_t^m B_t^m / (P_t Y_t)$, $R_{t-1,t}^m = (1 + \rho P_t^m) / P_{t-1}^m$ is the realized return of the long term bond, and $s_t = S_t / (P_t Y_t)$ is the primary surplus as a fraction of GDP.

Monetary and Fiscal Rules

The Central Bank moves the FFR according to the rule:

$$\frac{R_t}{R^*} = \left(\frac{R_{t-1}}{R^*} \right)^{\rho_R(\xi_t)} \left[\left(\frac{\Pi_t}{\Pi^*} \right)^{\psi_\pi(\xi_t)} \left(\frac{Y_t}{Y_t^n} \right)^{\psi_y(\xi_t)} \right]^{(1-\rho_R(\xi_t))} \sigma_R e^{\epsilon_{R,t}} \quad (7)$$

where R^* is the steady-state (gross) nominal interest rate, Y_t^n is natural output, Π^* is the target level for gross inflation, and the fiscal authority moves taxes according to the following rule:

$$\tilde{\tau}_t = \rho_\tau \tilde{\tau}_{t-1} + (1 - \rho_\tau) \left[\delta_b(\xi_t) \tilde{b}_{t-1}^m + \delta_e \tilde{e}_t + \delta_y (\hat{y}_{t-1} - \hat{y}_{t-1}^n) \right] + \sigma_\tau \epsilon_{\tau,t} \quad (8)$$

where $\tilde{\tau}_t$ is the level of tax revenues with respect to GDP in linear deviations from the steady state ($\tau_t = T_t / (P_t Y_t)$), $\tilde{b}_t^m$ is the linear deviation of debt from the steady state and $\epsilon_{\tau,t}$ is an i.i.d. shock. Note that taxes also respond to the level of expenditure $\tilde{e}_t$.

In equations (7) and (8), ξ_t is an unobserved state variable capturing the monetary/fiscal policy combination that is in place at time t . The unobserved state takes on a finite number of values $j = 1, \dots, m$ and follows a Markov chain that evolves according to a transition matrix P . More details about the structure of this matrix will be provided below and they will be central to understand the implications of the model.

2.1 The linearized model

Once the model is solved, the variables can be rescaled in order to induce stationarity. The model is then linearized with respect to taxes, government expenditure, and debt, whereas it is loglinearized with respect to all the other variables. We obtain a system of equations:

1. IS curve:

$$\hat{y}_t = \frac{\Phi \gamma^{-1}}{1 + \Phi \gamma^{-1}} \hat{y}_{t-1} - \frac{1 - \Phi \gamma^{-1}}{1 + \Phi \gamma^{-1}} \left[\tilde{R}_t - E_t [\tilde{\pi}_{t+1}] + (\rho_d - 1) d_t \right] + \frac{E_t [\hat{y}_{t+1}]}{1 + \Phi \gamma^{-1}} + \frac{(\rho_a - \Phi \gamma^{-1}) a_t}{1 + \Phi \gamma^{-1}} \quad (9)$$

2. Phillips curve:

$$\tilde{\pi}_t = \frac{\kappa}{(1 + \beta)(1 - \Phi \gamma^{-1})} [\hat{y}_t - \Phi \gamma^{-1} [\hat{y}_{t-1} - a_t]] + \frac{1}{1 + \beta} \tilde{\pi}_{t-1} + \frac{\beta}{1 + \beta} E_t [\tilde{\pi}_{t+1}] \quad (10)$$

3. Natural output:

$$\hat{y}_t^n = \Phi \gamma^{-1} \hat{y}_{t-1}^n - \Phi \gamma^{-1} a_t \quad (11)$$

4. Monetary policy rule:

$$\tilde{R}_t = \rho_R(\xi_t) \tilde{R}_{t-1} + (1 - \rho_R(\xi_t)) [\psi_\pi(\xi_t) \tilde{\pi}_t + \psi_y(\xi_t) (\hat{y}_t - \hat{y}_t^n)] + \sigma_R \epsilon_{R,t} \quad (12)$$

5. Fiscal rule:

$$\tilde{\tau}_t = \rho_\tau \tilde{\tau}_{t-1} + (1 - \rho_\tau) \left[\delta_b(\xi_t) \tilde{b}_{t-1}^m + \delta_e \tilde{e}_t + \delta_y (\hat{y}_{t-1} - \hat{y}_{t-1}^n) \right] + \sigma_\tau \epsilon_{\tau,t} \quad (13)$$

6. Debt:

$$\tilde{b}_t^m = \beta^{-1} \tilde{b}_{t-1}^m + b^m \beta^{-1} \left(\hat{R}_{t-1,t}^m - \hat{y}_t + \hat{y}_{t-1} - a_t - \tilde{\pi}_t \right) - \tilde{\tau}_t + \tilde{e}_t \quad (14)$$

7. Return long term bond:

$$\hat{R}_{t,t+1}^m = R^{-1} \rho \hat{P}_{t+1}^m - \hat{P}_t^m \quad (15)$$

8. No arbitrage:

$$R_t = E_t [R_{t,t+1}^m] \quad (16)$$

9. Expenditure:

$$\tilde{e}_t = \rho_e \tilde{e}_{t-1} + \sigma_e \epsilon_{e,t} \quad (17)$$

10. Technology:

$$a_t = \rho_a a_{t-1} + \sigma_a \epsilon_{a,t} \quad (18)$$

11. Demand shock:

$$d_t = \rho_d d_{t-1} + \sigma_d \epsilon_{d,t} \quad (19)$$

If we define the vector θ containing the structural parameters of the model and the DSGE state vector S_t , then we can rewrite the system of equations described above in a more compact form:

$$\Gamma_0(\xi_t, \theta) S_t = \Gamma_1(\xi_t, \theta) S_{t-1} + \Psi(\xi_t, \theta) Q \epsilon_t + \Pi \eta_t \quad (20)$$

with η_t a vector containing the expectations errors and Q is a diagonal matrix containing the standard deviations of the shocks. Notice that the system of equations will differ according to the regime that is in place. In what follows, we will describe the assumption about the parameter values across the different regimes and the properties of the transition matrix P .

2.2 Fixed coefficients and determinacy regions

Before describing the features of the model with regime changes, it is useful to analyze the properties of its fixed coefficient counterpart. The two policy rules and the linearized budget constraint are key to determine existence and uniqueness of a solution:

$$\tilde{R}_t = \rho_R (\xi_t^{sp}) \tilde{R}_{t-1} + (1 - \rho_R) \psi_\pi (\xi_t^{sp}) \tilde{\pi}_t + \dots$$

$$\tilde{\tau}_t = \rho_\tau \tilde{\tau}_{t-1} + (1 - \rho_\tau) \delta_b (\xi_t^{sp}) \tilde{b}_{t-1}^m + \dots$$

$$\begin{aligned} \tilde{b}_t^m &= \beta^{-1} \tilde{b}_{t-1}^m + \dots - \tilde{\tau}_t + \tilde{e}_t + \tilde{t}p_t \\ &\rightarrow \tilde{b}_t^m = (\beta^{-1} - \delta_b (\xi_t^{sp})) \tilde{b}_{t-1}^m + \dots \end{aligned}$$

where for simplicity we have assumed $\rho_\tau = 0$.

Following Leeper (1991), we can distinguish four regions of the parameter space according to the behavior of policy makers. Monetary policy is defined as active when it reacts strongly to deviations of inflation from the target. The exact condition is generally a function of all parameters of the model, but it approximately coincides with the Taylor principle: React more than one to one to inflation, i.e. $\psi_\pi > 1$. Fiscal policy is passive to the extent that it *passively* accommodates the behavior of the monetary authority. This means that the fiscal authority will move taxes in response to deviations of debt from its steady state in order to keep it on a stable trajectory. In terms of parameter values, this boils down to making sure that $|\beta^{-1} - \delta_b| < 1$, that for reasonable parameter values implies $\delta_b > 1/\beta - 1$. Leeper (1991) shows that for two of the four regions a unique solution exists. These correspond to the Active Monetary/Passive Fiscal (AM/PF) and Passive Monetary/Active Fiscal (PM/AF). The former is the most familiar one: The Taylor principle is satisfied and fiscal policy is Ricardian, given that the fiscal authority moves taxes in order to keep the process for debt stable. We will label this policy combination as the *virtuous* regime. The second determinacy region (Passive Monetary/Active Fiscal) is less familiar. In this case, the monetary authority is relatively unresponsive to fluctuations in inflation, while the fiscal authority does not respond strongly enough to movements in the debt-to-GDP ratio. Under this regime, inflation has to move in order to keep debt on a stable path and, even in absence of distortionary taxation, fiscal shocks have an impact on output. With a slight abuse of language, we will label this regime *inflationary*. Finally, when both authorities behave independently (AM/AF) no equilibrium exists, whereas when both of them are passive (PM/PF) the economy is subject to multiple equilibria.

In applied work, a lot of attention has been devoted to the *standard* determinacy region

	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 following Leeper (1991).

and to the problem of indeterminacy (see Clarida et al. (2000) and Lubik and Schorfheide (2004)), whereas the flipped determinacy region has often been regarded as an implausible candidate to explain movements in the real economy. A popular argument is based on the idea that even if the government does not constantly move taxes in order to stabilize debt, that does not imply that it will never do it. In other words, even if agents observe the PM/AF regime for a while, this does not mean that they are going to expect such a situation to prevail forever.

We start from this argument to construct a model in which the presence of a period of PM/AF policy mix does not necessarily imply that the economy is subject to inflationary pressure. At the same time, we are interested in modeling the consequences of long lasting deviations to this regime. If it is certainly reasonable to assume that a deviation of few quarters should not imply that agents lose confidence about the commitment of the government to stabilize debt, the same cannot be said of a deviation that lasts for decades.

In Section 3.1, we start building the intuition using a model in which agents can exactly observe the behavior of policy makers. This model will serve as benchmark for the full model with learning that will be introduced in Section 3.2.

3 Regime changes and agents' beliefs

Consider the model described by the system of equations (9)-(19) subject to regime changes and assume that the evolution of the monetary/fiscal policy mix can be described by a three-regime Markov switching process whose transition matrix H is:

$$H = \begin{bmatrix} p_{11} & p_{12} & p_{13} \\ 1 - p_{22} & p_{22} & \\ 1 - p_{33} & & p_{33} \end{bmatrix}$$

We will make use of the following two guidelines to characterize the matrix H and the three regimes. First, fiscal and monetary authorities do not have to pursue their goals on a daily basis. Deviations from the Taylor principle are possible and the fiscal authority does not have to constantly move taxes in order to keep debt on target. What is truly necessary is

that over a medium-long horizon policy makers act responsibly and that agents understand this. In fact, it is quite reasonable that policy makers want to retain some flexibility in order to respond effectively to extraordinary events. To model this feature, we introduce two regimes. Regime 1 is the virtuous regime: the Taylor principle is satisfied and fiscal policy accommodates the behavior of the monetary authority (i.e. monetary policy is active and fiscal policy is passive, $\psi_\pi(\xi_t^{sp} = 1) = \psi_\pi^A > 1$ and $\delta_b(\xi_t = 1) = \delta_b^P > 1/\beta - 1$). Under regime 2, the central bank reacts less than one-for-one to inflation and the fiscal authority does not move taxes in response to movements in government debt (i.e., $\psi_\pi(\xi_t = 2) = \psi_\pi^P < 1$ and $\delta_b(\xi_t = 2) = \delta_b^A < 1/\beta - 1$). To capture the idea that these deviations are short lasting, we set the persistence of regime 2 to a relatively low value, i.e. $p_{22} \ll 1$.

Second, we want to allow for the possibility of long lasting deviations from the standard policy practice. Therefore, we characterize regime 3 as having the same parameters of regime 2, but different persistence: $\psi_\pi(\xi_t = 3) = \psi_\pi(\xi_t = 2) = \psi_\pi^P < 1$, $\delta_b(\xi_t = 3) = \delta_b(\xi_t = 2) = \delta_b^A < 1/\beta - 1$, and $p_{33} \gg p_{22}$. It is important to stress that even if the parameters entering the Taylor and fiscal rules are the same, the two regimes are in fact different. This is because the different persistence has deep implications on what agents expect about the future, as it will be illustrated in Section 3.1. Given that these deviations represent a substantive shift in the conduct of monetary and fiscal policies, we assume that when in the virtuous regime policy makers are more likely to engage in a short lasting deviation ($p_{12} > p_{13}$).

Summarizing, we make the following assumptions on the transition matrix H :

- A1** $p_{22} < p_{33}$, implying that the regime 3 is more persistent than regime 2.
- A2** $p_{12} > p_{13}$, implying that switches from the active regime to the short-lasting PM/AF regime are expected to be relatively common.

3.1 Perfect information

Before moving to the full model with learning, we will analyze the properties of the companion model in which agents can observe all aspects of the economy, including the regime that is in place at each point in time.

We calibrate the model using the estimates obtained by Bianchi and Ilut (2011) when fitting a slightly richer model to US data. The values are reported in Table 2. Bianchi and Ilut (2011) consider a fully credible permanent switch from the inflationary regime to the virtuous regime. If agents regard the regime they live in as prevailing forever, the first regime is non-Ricardian, while the second is not. However, when agents are aware of regime

Parameter	Value	Parameter	Value	Parameter	Value
$\psi_\pi (\xi^{sp} = 1)$	0.6244	δ_e	0.7045	$100\sigma_R$	0.1972
$\psi_\pi (\xi^{sp} = 2)$	2.3522	δ_y	0.0869	$100\sigma_\tau$	0.4564
$\psi_y (\xi^{sp} = 1)$	0.3716	ρ_e	0.995	$100\sigma_a$	0.6518
$\psi_y (\xi^{sp} = 2)$	0.1527	Φ	0.7779	$100\sigma_e$	0.3653
$\rho_R (\xi^{sp} = 1)$	0.8480	ρ_a	0.4540	$100\sigma_d$	6.9498
$\rho_R (\xi^{sp} = 2)$	0.8132	ρ_d	0.6125	$100\sigma_e$	0.3653
$\delta_{\tau,b} (\xi^{sp} = 1)$	0	κ	0.0128	p_{11}	0.9000
$\delta_{\tau,b} (\xi^{sp} = 2)$	0.0327	$100 \ln (\gamma)$	0.4896	p_{12}	0.0990
$\rho_\tau (\xi^{sp} = 1)$	0.7306	b^*	0.9644	p_{22}	0.7000
$\rho_\tau (\xi^{sp} = 2)$	0.8921	τ^*	0.1846	p_{33}	0.9900

Table 2: Parameter choices of the DSGE parameters and of the transition matrix diagonal elements based on Bianchi and Ilut (2011).

changes, agents' expectations play a crucial role in determining if a regime is Ricardian or not (see also Davig and Leeper (2007)).

When agents are aware of regime changes, standard solution methods do not apply. Instead, we need to use one of the solutions methods developed to handle Markov-switching general equilibrium models. The solution algorithm employed in this paper is based on the work of Farmer et al. (2010). The authors show that it is possible to reduce the task of finding a Minimal State Variable solution to that of computing the roots of a quadratic polynomial in several variables. When a MSV solution exists, it can be characterized as a regime switching vector-autoregression, of the kind studied by Hamilton (1989), Chib (1996), and Sims and Zha (2006):

$$S_t = T(\xi_t^{sp}, \theta, H) S_{t-1} + R(\xi_t^{sp}, \theta, H) Q \varepsilon_t \quad (21)$$

It is worth emphasizing that the law of motion of the DSGE states depends on the structural parameters (θ), the regime in place (ξ_t), and the probability of moving across regimes (H). This means that what happens under regime i does not only depend 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. In other words, agents' beliefs matter for the law of motion governing the economy. From now on, a more compact notation will be used: $T(\xi_t) = T(\xi_t, \theta, H)$ and $R(\xi_t) = R(\xi_t, \theta, H)$.

To facilitate the interpretation of the results, we combine the law of motion (21) with a system of observation equations including variables that often enter the economic debate.

The result is a model cast in state space form:

$$Y_t = D(\theta) + ZS_t \quad (22)$$

$$S_t = T(\xi_t^{sp}) S_{t-1} + R(\xi_t^{sp}) Q\epsilon_t \quad (23)$$

where Y_t is a vector containing the observables, D is a column vector containing the steady state values, Z is a matrix mapping the Markov-switching law of motion (23) into the observables. We reconstruct the following observables: real GDP growth rate, annualized quarterly inflation, annualized quarterly FFR, and debt to GDP ratio on a quarterly basis.

The simplest way to understand the properties of the different regimes is to look at impulse responses. Figure 1 contains the results. We shall start focusing on the response to an expenditure shock, reported in the last row. The difference between the long lasting PM/AF regime and the other two regimes is particularly striking. Under the virtuous regime and the short lasting PM/AF regime, this shock does not have any effect on inflation and output, whereas under the long lasting PM/AF regime we observe a large and persistent increase in inflation and an expansion in output. Under the virtuous regime and the short lasting PM/AF regime, the debt-to-GDP ratio starts increasing slowly and steadily in response to the increase in expenditure. The two paths differ only to the extent that under the virtuous regime the government is increasing taxes in response to the increase in debt. Under the PM/AF regime we observe a sudden drop in the debt-to-GDP ratio, due to higher expected future short term interest rates, and then a smooth decline as a result of the high inflation. Then the variable goes back to the steady state from below because of the increased level of expenditure.

The first row reports the responses to a monetary policy shock. Under all regimes, the Federal Reserve retains the ability to generate a recession and a subsequent short run decline in inflation. However, under the long lasting PM/AF regime, the initial decline in inflation fires back. This "stepping on a rake" effect (Sims (2009)) implies that the Central Bank might have the illusion of being able to control inflation, even if this ability is in fact lost the moment that its actions are not adequately supported by the fiscal authority. The response of the debt-to-GDP ratio is also substantially different when the long lasting PM/AF regime is in place: Under the virtuous regime and short lasting PM/AF, the ratio increases quickly due to the decline in output and high real interest rates, whereas under the long lasting PM/AF regime we observe a sudden drop caused by a value loss, then a modest increase due to the slowdown of the economy, and finally a smooth decline as a consequence of the high inflation. Notice that under the short lasting PM/AF regime, inflation declines smoothly and the debt-to-GDP ratio increases without showing any revaluation effect. This occurs despite

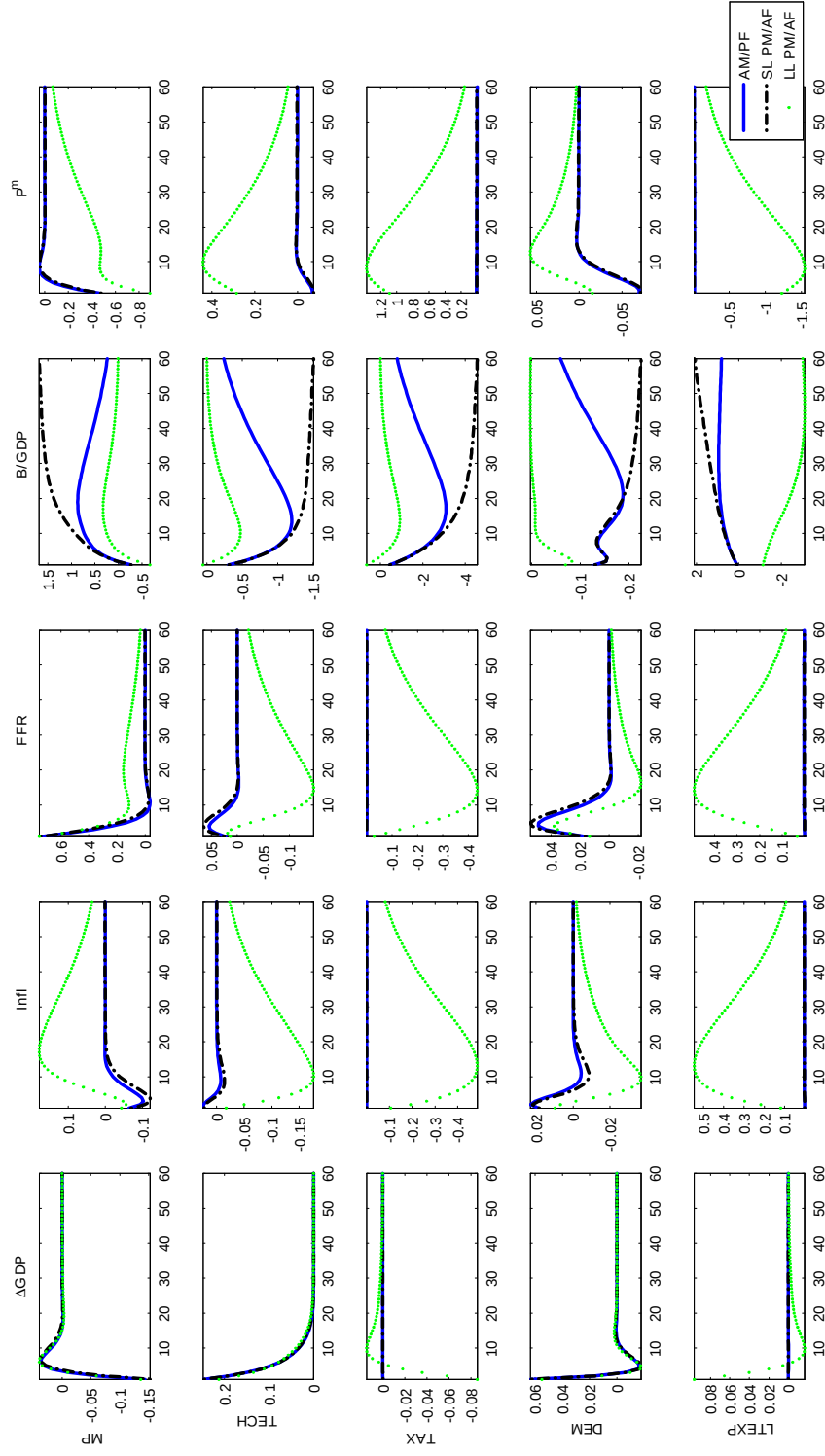


Figure 1: Impulse responses under perfect information.

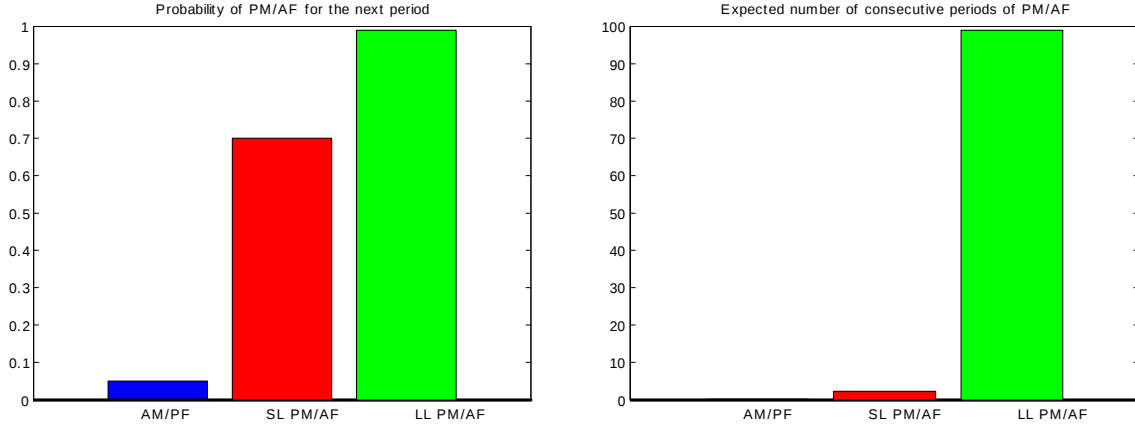


Figure 2: The two columns report respectively the one-step-ahead probability of entering a period of PM/AF policy and the expected number of consecutive periods of PM/AF under the different regimes assuming that agents have perfect information.

the fact that the taxation rule in place at the time of the shock determines an increase in the debt-to-GDP ratio that could appear to be "permanent" to an external observer. Summarizing, while the long lasting PM/AF is still an inflationary regime, the short lasting PM/AF is not, even if policy makers behave in the same way.

From these impulse responses, it should be clear that while the short lasting PM/AF regime is a Ricardian regime, the same cannot be said of the long lasting PM/AF regime. The interesting fact here is that the behavior of the two authorities is *identical* across the two regimes. The two regimes differ to the extent that they induce different expectations for the future. To illustrate this point, for each regime, Figure 2 reports the one-step-ahead probability of being in the PM/AF regime next period and the expected number of consecutive deviations from the virtuous policy mix. When the economy is under the virtuous regime, agents are confident of staying there for a while and the expected number of consecutive deviations is very low. When under the short lasting PM/AF regime, the one-step-ahead probability increases substantially, but the expected number of consecutive deviations is still very low (2.33). Finally and most importantly, when the economy moves to the long lasting PM/AF regime, the number of consecutive deviations expected by the agents increases substantially.

The results shown above allow us to make the first important point: In a model with recurrent regime changes the policy mix is not enough to establish if a regime is Ricardian or not. Instead, the persistence of the regime becomes a key ingredient given that it affects agents' expectations about the conduct of fiscal and monetary policy in the medium and

long run. When agents are confident about a prompt return to the virtuous policy mix, Ricardian equivalence holds, as is the case for the short lasting PM/AF regime.

3.2 Bayesian Learning

We are now ready to analyze the case in which agents cannot observe the regime they are in. Let $\mathcal{F}_t$ be the information set of the forward-looking agents (i.e., households and firms). It is assumed that agents observe the history of the endogenous variables as well as the history of the structural shocks, including the monetary policy shock. However, agents do not observe the history of regimes. Instead, they need to infer their evolution to form expectations about future realizations of forward-looking variables. Agents conduct Bayesian learning over regimes and regime changes are modeled as the three-regime Markov switching process described above. In this context, the transition matrix H also reflects agents' priors about the evolution of the monetary/fiscal policy mix.³

Note that since agents know the history of endogenous variables and shocks, they can exactly infer the policy mix that is in place at each point in time. While the virtuous regime is fully revealing, agents do not know whether the short-lasting regime 2 or the long-lasting regime 3 is in place when the PM/AF mix prevails. Agents, thus, have to learn the nature of the deviation from the virtuous regime in order to form expectations over the endogenous variables of the economy.

An important result is then the following: *Agents will grow more and more pessimistic about moving back to the virtuous regime, the longer the time spent under the inflationary regime.* To see this, note that after having observed $\tau \geq 1$ consecutive deviations from the virtuous regime, agents believe that policy makers will keep deviating in the next period $t + 1$ with probability:⁴

$$prob\{s_{t+1} \neq 1 | \mathcal{F}_t\} = \frac{p_{12} \left(\frac{p_{22}}{p_{33}} \right)^\tau + p_{13}}{\frac{p_{12}}{p_{22}} \left(\frac{p_{22}}{p_{33}} \right)^\tau + \frac{p_{13}}{p_{33}}}. \quad (24)$$

The probability $prob\{s_{t+1} \neq 1 | \mathcal{F}_t\}$ has a number of properties that shed light on the key features of the learning mechanism. Since $p_{22} < p_{33}$, this probability is monotonically

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

⁴This result basically comes from applying the Bayes' theorem and then combining the resulting probabilities with the transition matrix P . See Bianchi and Melosi (2011) for a detailed derivation.

increasing with respect to the number of last consecutive deviations τ . That is, for any $\tau \geq 1$

$$\frac{\partial \text{prob}\{s_{t+1} \neq 1 | \mathcal{F}_t\}}{\partial \tau} = \frac{p_{12} \left(\frac{p_{22}}{p_{33}}\right)^\tau \left(1 - \frac{1}{p_{22}}\right) \ln\left(\frac{p_{22}}{p_{33}}\right)}{\left[\frac{p_{12}}{p_{22}} \left(\frac{p_{22}}{p_{33}}\right)^\tau + \frac{p_{13}}{p_{33}}\right]^2} > 0$$

As the number of periods τ in which the PM/AF policy mix has prevailed, agents will become more and more pessimistic about the odds of switching to the virtuous regime in the next period. The reason is that as the authorities keep deviating from the virtuous regime, agents get increasingly convinced that they are engaging in a long-lasting deviation (regime 3) from where switching to the virtuous regime is more unlikely ($p_{22} < p_{33}$).

Furthermore, agents' pessimism admits an upper and lower bound. If policy makers deviate from the virtuous regime for a very long time, agents will eventually get convinced of being in the long lasting PM/AF regime and the probability of observing the PM/AF policy mix in the next period degenerates to the persistence of such a regime:

$$\lim_{\tau \rightarrow \infty} \text{prob}\{s_{t+1} \neq 1 | \mathcal{F}_t\} = p_{33} \quad (25)$$

Hence, p_{33} is the upper bound for agents' pessimism. This implies that for each $\varepsilon > 0$, there exists an integer τ^* such that:

$$p_{33} - \text{prob}\{s_{t+1} \neq 1 | \tau = \tau^*\} < \varepsilon \quad (26)$$

with the important result that for any $\tau > \tau^*$ agents' beliefs can be effectively approximated using the properties of the long lasting PM/AF regime.

As far as the lower bound is concerned, when agents observe policy makers deviating for the first time (i.e., $\tau = 1$), then equation (24) shows that the probability of staying in the passive regime is an average of the persistence of the two passive regimes p_{22} and p_{33} with weights $p_{12}/(p_{12} + p_{13})$ and $p_{13}/(p_{12} + p_{13})$. This weighted average is the lower bound for agents' pessimism. The smaller the conditional probability $p_{13}/(p_{12} + p_{13})$, the closer the lower bound will be to p_{22} .

The intuition behind such a lower and upper bound for the waves of agents' pessimism goes as follows. When agents observe policy makers deviating from the virtuous regime for the first time ($\tau = 1$), they don't know if they entered the long lasting or the short lasting deviation. Then, the weight that they assign to a long lasting deviation depends on the ratio p_{12}/p_{13} , excluding the degenerate case in which one of these two probabilities is zero. Consequently, the probability of observing another deviation next period will be a weighted average of p_{22} and p_{33} . As policy makers keep deviating, agents get increasingly

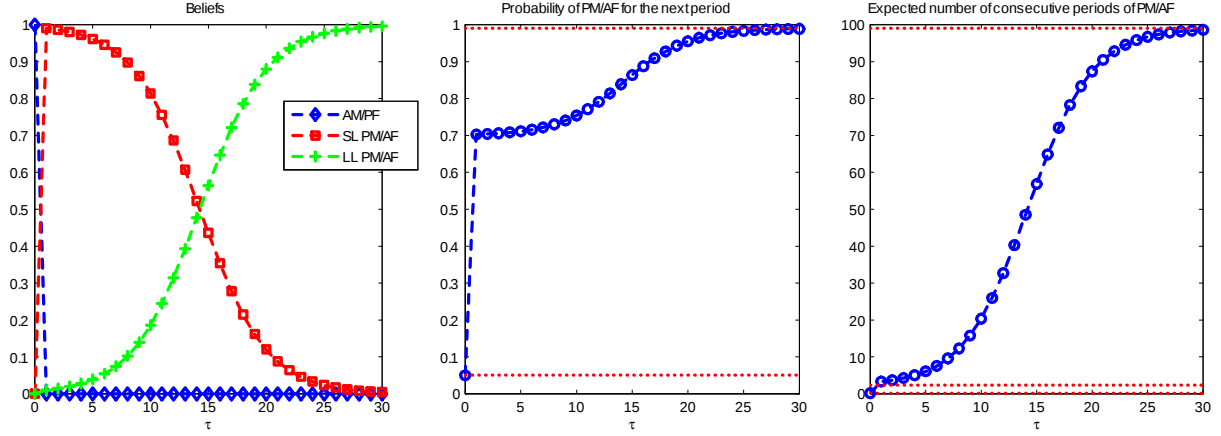


Figure 3: From left to right, the three columns describe, as a function of the number of consecutive deviations τ , the evolution of agents' beliefs, the one-step-ahead probability of observing the PM/AF policy mix, and the expected number of consecutive deviations.

more convinced that the economy entered the long-lasting PM/AF regime. Since the short lasting regime is characterized by low persistence (i.e., $p_{22} < p_{33}$), the probability of staying in the PM/AF regime in period $t + 1$ will increase as the weight assigned to p_{22} is monotonically decreasing. When policy makers have deviated from the virtuous regime for a sufficiently large number τ^* of periods, agents are then sure to be in the long-lasting PM/AF regime. Consequently, their pessimism will reach its upper bound, which is the probability that next period's policy mix will be again PM/AF conditional on being in the long-lasting passive regime, p_{33} .

These ideas are summarized in Figure 3. The first column describes the evolution of agents' beliefs as a function of the number of observed deviations from the virtuous regime. The virtuous regime is fully revealing, therefore agents do not face any uncertainty.⁵ When agents observe the first deviation, they are relatively confident that the prevailing regime is the short lasting PM/AF regime, given the assumption $p_{12} > p_{13}$. However, as the number of deviations grows, agents become more and more convinced that the economy entered the long lasting regime. This has important implications on agents' expectations regarding the future behavior of policy makers. The second and third columns of Figure 3 report the one-step-ahead probability of observing the PM/AF policy mix and the expected number of deviations implied by the drift in beliefs. As agents observe more and more deviations, they become more and more pessimistic and the expected number of consecutive deviations eventually coincides with the one prevailing under the long lasting PM/AF regime. Later

⁵In section DDD we will relax this assumption, extending the model to have a short lasting and a long lasting AM/PF regime. TO BE ADDED.

on we will show that this drift in beliefs about the future behavior of policy makers has deep implications for the way shocks propagate into the economy. However, first we need to explain how the model with learning is solved.

3.2.1 Solving the model with learning

It is very important to emphasize that the evolution of agents' beliefs about the future conduct of fiscal and monetary policy plays a critical role in the Markov-switching model with learning. In fact, unlike the perfect information model described in Section 3.1, the dynamics of the endogenous variables in the model with learning cannot be fully captured by the three policy regimes (i.e., virtuous, short-lasting PM/AF, and long-lasting PM/AF). Instead, agents expect different dynamics for next period's endogenous variables depending on the degree of their pessimism about a return to the virtuous regime.

Therefore, learning requires expanding the number of regimes and re-defining them as a combination between policy makers' behavior and agents' beliefs. Such new regimes reflect different degrees of pessimism while agents are learning about the persistence of the deviation from the virtuous regime. Bianchi and Melosi (2011) show that the Markov-switching model (9)-(19) with three regimes s_t and learning can be recasted in terms of an expanded set of $(\tau^* + 1) > 3$ new regimes. The increased number of regimes captures the degree of pessimism associated with observing deviations from the virtuous regime for $\tau = 1 \dots \tau^*$ periods, where $\tau^* > 0$ is define by the condition (26). The structural parameters for the expanded system of equations are defined as

$$\theta(i) = \begin{cases} \theta^{AM/PF}, & \text{if } i = 1, \text{ i.e. } \tau = 0 \\ \theta^{PM/AF}, & \text{if } i > 1, \text{ i.e. } \tau > 1 \end{cases}$$

and the transition matrix $\tilde{\mathcal{H}}$ is defined as:

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

where the total $\tau^* + 1$ regimes is given by:

$$\left[\left(\theta^{AM/PF}, \tau = 0 \right), \left(\theta^{PM/AF}, \tau = 1 \right), \left(\theta^{PM/AF}, \tau = 2 \right), \dots, \left(\theta^{PM/AF}, \tau = \tau^* \right) \right]$$

Hence, one can recast the Markov-switching DSGE model with learning in (9)-(19) as a Markov-switching Rational Expectations system, in which the regimes are re-defined in terms of realized duration of the passive regimes, τ_t . This result allows us to solve the model with regime switches and learning by applying any of the standard methods developed to solve this new class of models. In this paper, we apply the methodology derived by Farmer et al. (2010).

It is worth emphasizing that this way of recasting the learning process allows us to easily model the behavior of agents that are aware of the fact that their beliefs will change in the future according to what they observe in the economy. This represents a substantial difference with the anticipated utility approach in which agents form expectations without taking into account that their beliefs about the economy will change over time. Furthermore, the approach described above differs from the one traditionally used in the learning literature in which agents form expectations according to a reduced form law of motion that is updated recursively (for example OLS regressions). The advantage of adaptive learning is the extreme flexibility given that, at least in principle, no restrictions need to be imposed on the type of parameter instability characterizing the model. However, such flexibility does not come without a cost, given that agents are not really aware of the model they live in, but only of the implied law of motion. Instead, in this paper agents fully understand the model and they are aware of the trade-offs that characterize it. They are uncertain about the future behavior of policy makers and this has important consequences for the law of motion of the economy, as shown below.

3.2.2 Impulse responses

In order to understand the properties of the model, we will start illustrating how learning affects the propagation of the shocks. Figure 4 contains impulse responses conditional on different starting values of τ and assuming that the PM/AF regime is in place over the entire horizon. The dark/reddish colors correspond to large *starting* values for τ , while as the colors become lighter and lighter turning into light blue, the starting number of deviations falls to 1 (i.e. at the time of the shock agents observe the first deviation to the PM/AF regime). We do not report here the response under the virtuous regime because this would look very

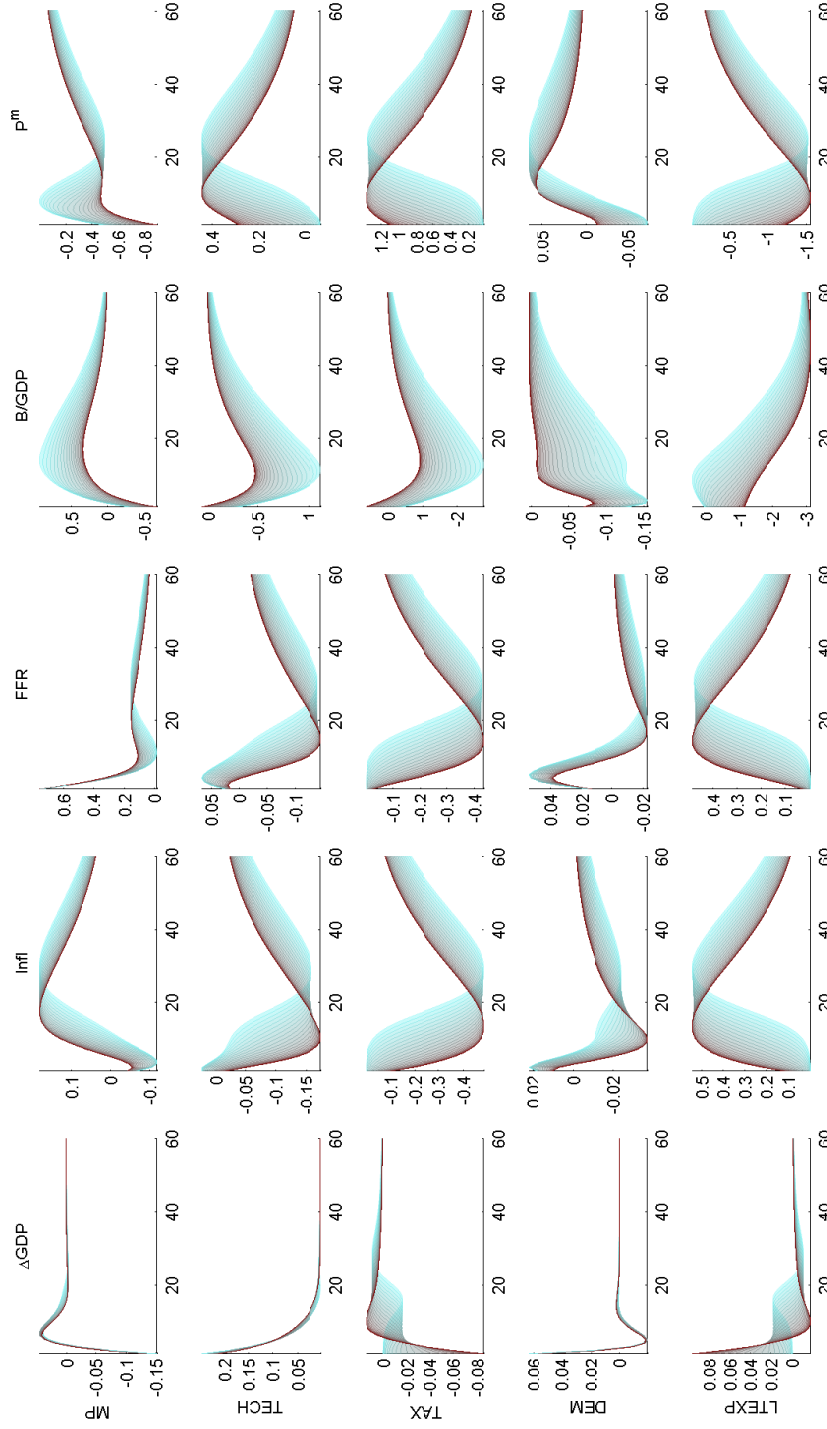


Figure 4: Impulse responses under learning assuming that the PM/AF regime prevails over the relevant horizon. Moving from the light-blue to the dark-red, the initial number of observed deviations increases. The impulse responses under the AM/PF are very similar, although not identical, to the ones that prevail under perfect information.

similar to the one prevailing under perfect information, as the regime is fully revealing.⁶

Before proceeding, it is worth stressing an important point. The assumption that the PM/AF regime prevails over the entire horizon implies that the number of observed deviations τ grows over time. This in turn determines a progressive change in the law of motion as agents become more and more convinced of being in the long lasting PM/AF regime. The law of motion then stabilizes in the moment agents are certain that they entered a long lasting deviation ($\tau = \tau^*$). The law of motion would change again in the moment agents were to observe a return to the virtuous regime.

Fiscal expenditure

We shall start considering the responses to a fiscal expenditure shock when agents have observed a large number of consecutive deviations. In this case agents are substantially convinced of being in the long lasting PM/AF regime. As a result, the impulse responses resemble very closely the ones implied by the same regime under perfect information.⁷ Following a shock to government expenditure, inflation increases on impact and reaches its peak after 12 quarters. At the same time, the debt-to-GDP ratio experiences a discrete jump as a result of higher growth, larger inflation, and a drop in the price of long term bonds.

When the initial number of deviations is low, these effects are initially mitigated because agents do not know the nature of the observed deviation. Initially inflation and GDP growth barely move, even if the current behavior of policy makers is unchanged. Furthermore, we do not observe the jump in the debt-to-GDP ratio, given that agents are fairly confident that the government will eventually increase taxes, and there is no significant change in real interest rates and output growth. However, as agents observe more and more deviations, their expectations start drifting, the law of motion evolves, and the non-Ricardian dynamics start playing an important role. Inflation starts increasing smoothly and persistently and reaches its peak after approximately eight years. Symmetrically, output starts growing, real interest rates decline, and the debt-to-GDP ratio falls.

The ability to control inflation

When the initial number of deviations is small, in response to a monetary policy shock inflation declines on impact and stays below the steady state for several periods (around three years in the example considered here). However, as agents become aware of the possibility that the economy is going through a long lasting deviation, inflation starts increasing and

⁶Nevertheless the impulse responses would not be *identical* because the uncertainty that prevails under the PM/AF regime also affects the law of motion under the virtuous regime.

⁷However, even when agents think that they are in the long-lasting PM/AF regime with probability one, the law of motion still slightly differs from the one implied by the model with perfect information because agents' expectations about the future reflect the additional uncertainty deriving from the learning mechanism.

the stepping on a rake effect appears. If agents have already observed a large number of deviations, the entire sequence of events occurs more quickly and inflation stays below the steady state for only few years. These dynamics have two important implications. First, when the initial number of deviations is small, a central bank might be induced to think that everything is fine for a long time, given that the stepping on a rake effect does not immediately manifest itself. Second, as policy makers keep deviating and the ability of the central bank to control inflation deteriorates, a central bank might erroneously be induced to think that structural changes are occurring in the economy that are making the sacrifice ratio less favorable.

4 Dormant shocks and Fiscal Virtue

As shown in Section 3.2.2, when learning is introduced in the model with regime changes, the economy responds gradually to the shocks as agents update their beliefs about the future behavior of policy-makers. The response to fiscal shocks is particularly interesting, given that the learning mechanism can substantially prolong their effects and move the peak of the responses further into the future. In this section, we will analyze these features more in details introducing the notion of *dormant shocks* and characterizing their effects as a function of *fiscal virtue*.

4.1 Dormant shocks

Figure 5 considers a one standard deviation increase in expenditure occurring at time 0, followed after 5 years by a change in the monetary/fiscal policy mix from the virtuous regime to the PM/AF regime. The left panel reports the impulse responses while the right panel contains the evolution of expected volatility at different horizons, from 1 year (light blue) to 5 years (dark red). This measure of uncertainty is computed taking into account the possibility of regime changes and the evolution of agents' beliefs.⁸

Notice that as long as the virtuous regime prevails the effects on inflation, output, and FFR are basically undetectable as agents expect taxes to be raised in order to repay the growing debt. However, as soon the policy mix changes, the learning process begins. At this point an external observer that were focusing exclusively on the three standard macro-economic variables would be observing a slow moving increase in inflation, an acceleration in output growth (and a positive output gap), combined with a weak response of the FFR. All of these changes would be without any apparent explanation, as no new shocks have oc-

⁸Please refer to Bianchi (2011) for technical details.

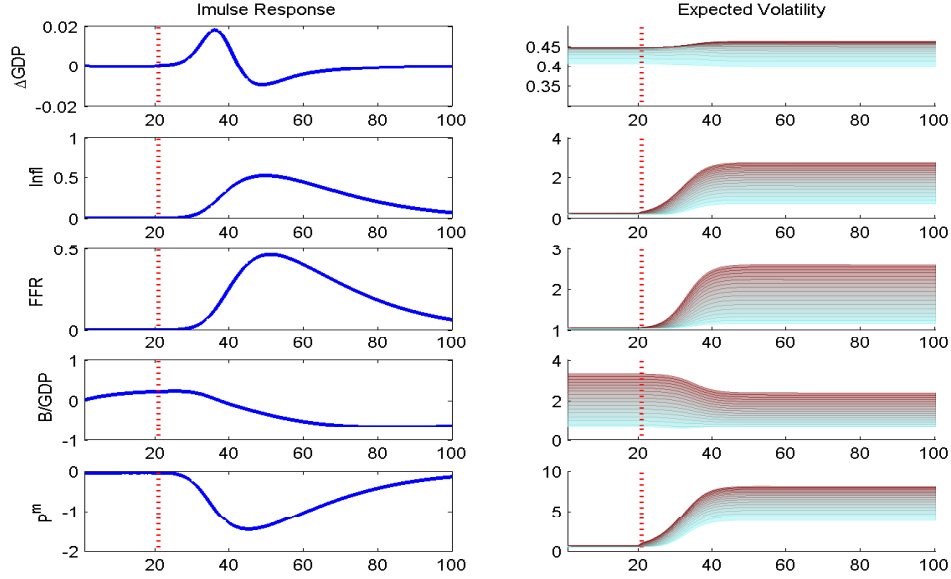


Figure 5: The two columns report the evolution of the endogenous variables and the correspondent expected volatilities assuming an expenditure shock occurring at time 0 and a regime change from the AM/PF to the PM/AF regime after five years. In the right column, moving from the light blue to the dark red the time horizon increases from one to five years. Expected volatilities are computed taking into account the possibility of regime changes.

curred. Fiscal shocks have therefore an interesting property in this environment: They can manifest themselves many years after they occurred. In the meantime, they are just *dormant shocks*, given that they do not have any apparent effect on the three standard macroeconomic variables. Notice that this aspect makes them very hard to identify. If an econometrician were trying to understand the causes of the slow-moving increase in inflation, he might be tempted to conclude that a change in the target for inflation occurred. On the other hand, he might want to include fiscal variables in order to estimate the model under the assumption that a non-Ricardian regime is in place. However, if he happens to exclude the early years of the sample, he might have a very hard time trying to recover any movement in the fiscal variables that could in fact explain the slow moving increase in inflation.

The increase in inflation is not the only effect of the changed economic environment. As outlined in the right column, agents also face an increase in uncertainty. The expected volatility smoothly increases as agents become more and more convinced of having entered a prolonged period of PM/AF policy mix. Dormant shocks have therefore another interesting effect: After many years they can cause an increase in the volatility of the endogenous variables and consequently in agents' uncertainty. Once again, these effects are dormant as

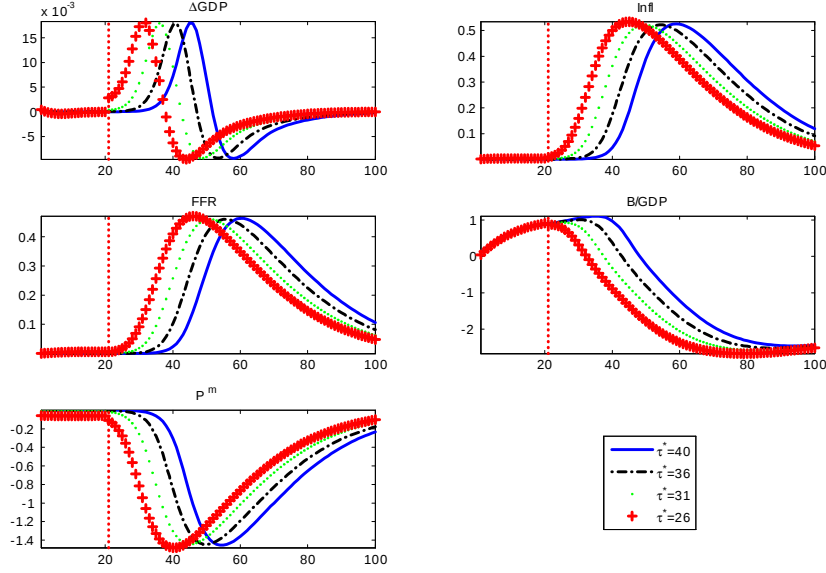


Figure 6: The figure considers the effects of a "dormant shock" to fiscal expenditure for transition matrices that differ according to the a-priori relative probability of a short lasting deviation. The shock occurs at time 0, while the regime change occurs after 20 periods (red vertical bar). The different a-priori beliefs are captured by the different periods necessary to convince agents that they entered a long lasting deviation (τ^*).

long as the economy is under the virtuous regime.

Summarizing, an observer that were monitoring the evolution of our hypothetical economy would be detecting a progressive increase in volatility and uncertainty, measured by *expected* volatility. At the same time, she would observe a smooth increase in inflation that seems to gain momentum over time. Furthermore, while output growth and inflation move in the same direction during the run-up of inflation, the correlation inverts sign once inflation reaches its peak. Therefore, we observe an episode of stagflation, with high inflation and low growth. The increase in the volatility of inflation has three causes. First, given that the Fed reacts less strongly to deviations of inflation from the target, any shock has a larger *direct* impact on the dynamics of inflation. Second, any shock that moves the debt-to-GDP ratio is also going to have an *indirect* impact on all the macroeconomic variables. Third, the expenditure and taxation shocks that are neutral in a Ricardian world, start having larger and larger effects as agents' beliefs drift over time.

$100p_{13}/(p_{12} + p_{13})$	p_{22}	τ^*	$100p_{13}/(p_{12} + p_{13})$	p_{22}	τ^*
.04	0.70	40	1.00	.90	97
.20	0.70	36	1.00	.80	48
1.00	0.70	31	1.00	.70	31
5.00	0.70	26	1.00	.60	23

Table 3: Parameter values used in the study of dormant shocks. The persistences of the long lasting PM/AF regime and of the AM/PF regime are fixed at .99 and .95, respectively.

4.2 Fiscal Virtue

The previous section has emphasized that dormant shocks can have effects many years after they occurred. In this section we will elaborate more on this point, trying to understand what determines the lag between the time of the regime change and the peak of the inflation increase that such a regime change triggers.

Figure 6 considers the same exercise of the previous subsection for different values of the ratio $p_{13}/(p_{12} + p_{13})$. Recall that this ratio controls agents' a-priori beliefs of entering a long lasting versus a short lasting deviation. In other words, it determines the probability attached to the long lasting regime once agents observe the first realization of the PM/AF policy mix. As this ratio declines, agents are a-priori more and more optimistic about the possibility of facing only a temporary deviation to the PM/AF. Consequently, it takes longer for agents to get convinced that they entered a long lasting deviation. To capture this idea, the different curves are labelled according to the implied τ^* , i.e. the number of deviations required for agents' beliefs to approximately coincide with the ones implied by the long lasting PM/AF regime. As explained in Subsection 3.2 this value represents an upper bound on agents' pessimism. The dotted green line represents the benchmark case in which $p_{13}/(p_{12} + p_{13}) = 1\%$ and $\tau^* = 31$. Table 3 summarizes the mapping for the other three curves.

As the ratio $p_{13}/(p_{12} + p_{13})$ declines and τ^* increases, the peak of the inflation spur moves to the right. When agents attach a conditional probability of .04% to the long lasting regime, the peak in inflation occurs almost 15 years after the shock took place and 10 years after the regime change occurred. When instead agents are relatively pessimistic and $p_{13}/(p_{12} + p_{13}) = 5\%$, the learning process is faster and the peak of inflation occurs only 6/7 years after the regime change. How should we interpret these changes? Given that the ratio $p_{13}/(p_{12} + p_{13})$ controls the a-priori beliefs of agents, it is capturing the credibility of policy-makers in agents' eyes. The most rigorous assumption would imply that agents' a-priori beliefs are based on some historical evidence, in which case the matrix H would be pinned down by the relative frequency of short lasting and long lasting deviations. Alternatively, we could imagine that

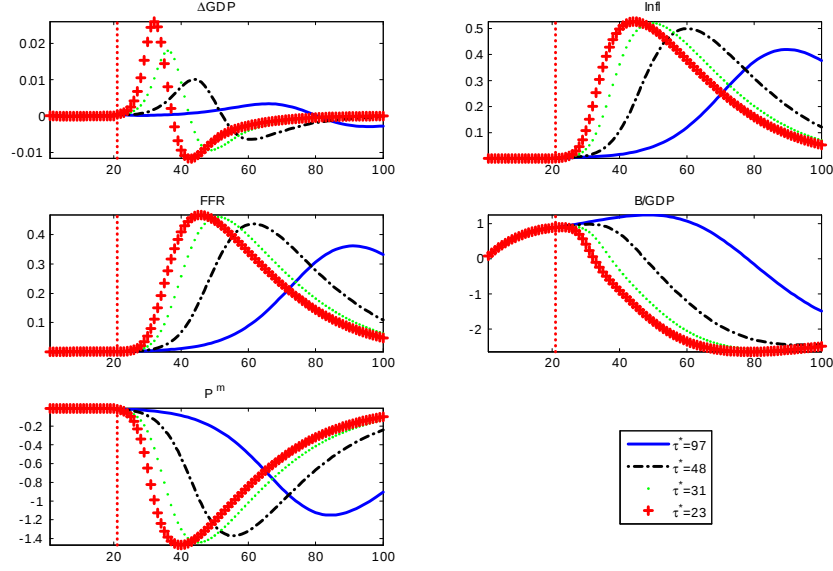


Figure 7: The figure considers the effects of a "dormant shock" to fiscal expenditure for transition matrices that differ according to the relative persistence of the two PM/AF regimes. The shock occurs at time 0, while the regime change occurs after 20 periods (red vertical bar). The different a-priori beliefs are captured by the different periods necessary to convince agents that they entered a long lasting deviation (τ^*).

agents form subjective conjectures about how likely it is that the government will engage in a persistent deviation from the virtuous. In other words, agents could retain the occurrence of a long lasting deviation to the PM/AF regime almost impossible, simply because they do not believe that the government can decide not to increase taxes in order to repay debt. Or, instead, agents might be very skeptical about the commitment to fiscal stability because of some previous events. However, no matter what agents' a-priori beliefs are and where they come from, *as long as agents update them according to what they observe, the government cannot indefinitely avoid increasing taxes*. In other words, no matter how optimistic agents are, if the government deviates for a long period of time, eventually it will induce a change in expectations leading to an increase in inflation and uncertainty. At the same time, if the government has been virtuous in the past, it has probably built some reputation for avoiding long lasting deviations. This translates into a low value for $p_{13}/(p_{12} + p_{13})$ and implies that policy makers can deviate for a longer period of time without losing control of inflation expectations.

However, the a-priori relative probability of the two deviations is not the only margin that affects the timing of the peak of inflation. The relative persistence of the short and

long lasting deviations, p_{22}/p_{33} , is also important. When p_{22}/p_{33} is low, the learning process is faster as agents need only few consecutive observations to conclude that they entered a long lasting deviation. In the limiting case in which the ratio is zero, agents just need two consecutive deviations to conclude that they entered a long lasting regime and that with very high probability they will face a long series of PM/AF realizations. On the other hand, when p_{22}/p_{33} is large the learning process unfolds very slowly and consequently the peak of inflation moves further to the right. Figure 7 illustrates this point. The benchmark case is once again represented by the dotted line and the parameterizations are summarized in Table 3. Notice that when $p_{22}/p_{33} = .9/.99 = 0.4762$ the peak of inflation occurs more than 20 years after the shock occurred and more than 15 years after the regime took place. Even in this case, the ratio can be interpreted as characterizing policy makers' credibility, but across a different dimension. Specifically, agents might have different views about what it means for a deviation to be short lasting. When, for a given persistence of the long lasting regime, this ratio increases, it means that agents can tolerate a longer series of deviations before deciding that they entered a long lasting PM/AF regime. Even in this case, the relative persistence of the two regimes can be the result of some past evidence or determined by an arbitrary conjecture about what it means for a regime to be short lasting. What matters is that the persistences of the two regimes differ largely enough to make the distinction meaningful. Furthermore, it is important to keep in mind that the characterization of one regime affects the laws of motion of all the others. This implies that for a given set of parameters there is a limit to how large the ratio p_{22}/p_{33} can be made without causing the short lasting regime, and possibly the virtuous regime, to be inflationary.

Learning makes the unfolding of the effects of dormant shocks smooth, a property that seems appropriate to characterize inflation dynamics in economies, such as the US, with a strong reputation. Countries for which the commitment to fiscal responsibility is less clear are more likely to be subject to sudden shifts in agents' expectations as agents need only a few deviations in order to decide that the economy entered a non-Ricardian regime. This suggests an interesting interpretation of the different impulse responses considered in this subsection: Following a shock of the same magnitude, countries with different levels of fiscal virtue might experience similar levels of inflation as long a virtuous regime is in place. However, once the two economies experience a deviation from the virtuous regime, substantial inflation differentials would arise as the speed of learning greatly differs across the two countries.

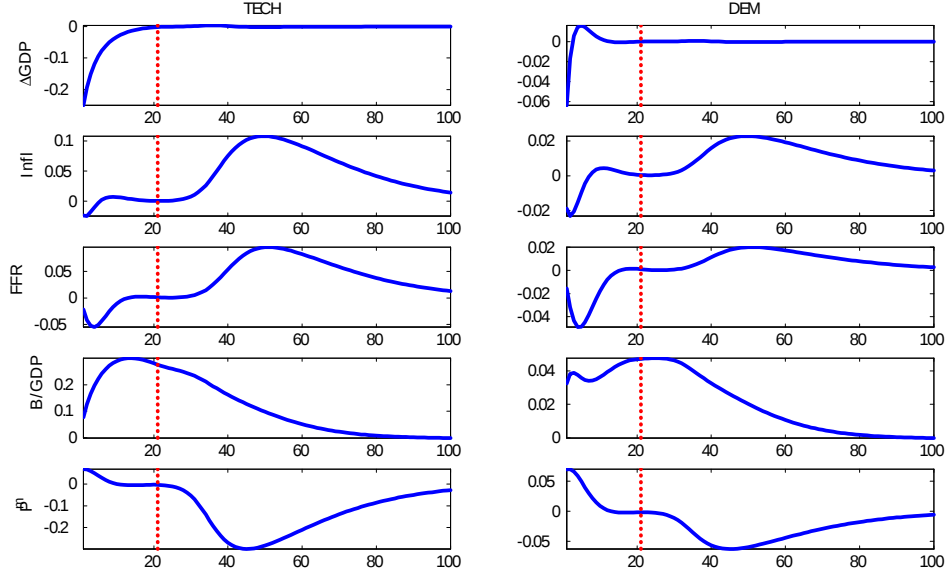


Figure 8: The two columns report the evolution of the endogenous variables in response to (negative) shocks to technology and preferences assuming a regime change from the AM/PF to the PM/AF regime occurring after five years (red dashed vertical line).

4.3 Dormant Technology and Demand Shocks

Figure 8 considers the same sequence of regime changes focusing on (negative) demand and technology shocks. Now the shocks have some effects in the short run, as they both move output and inflation and trigger a response by the Federal Reserve. However, after few years the economy seems back to the steady state until the regime change occurs. Once again the learning process gradually determines an increase in inflation as agents' expectations about the future become more and more grim.

These results outline the important point that all shocks have a dormant component when an economy is subject to fluctuations between different regimes. This is because all shocks move the debt-to-GDP ratio, making the economy subject to the possibility of a disanchoring of expectations once policy makers deviate from the virtuous regime.

5 A Look at the Past...

In the previous section, we have introduced the concept of dormant shocks and shown how they can propagate slowly over time and have the largest impact many years after they took place. We will now put the theory to work showing how a few shocks, combined with the

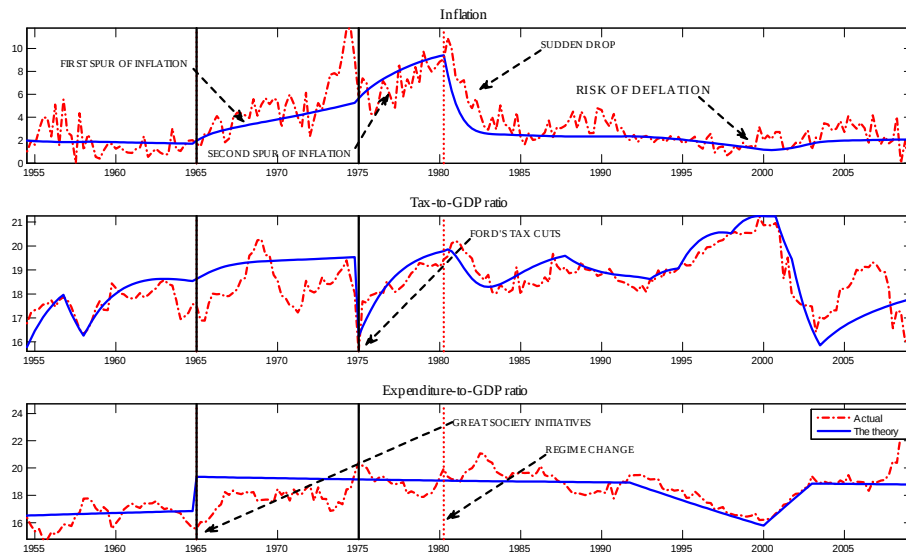


Figure 9: The figure shows the results for a simulation meant to illustrate the properties of the model with learning. Four events are key. First, a large shock to the long term component of expenditure and a switch from the AM/PF to the PM/AF regime assumed to coincide with the first reference to the Great Society made by President Johnson (first solid vertical line). Second, the Ford's tax cut (second solid vertical line). Third, the switch from the PM/AF to the AM/PF regime a few quarters after the appointment of Volcker (dashed vertical line). Fourth, the large primary surpluses of the '90s, captured by a series of favorable shocks to tax revenues and expenditure.

learning mechanism, can go a long way in explaining the historical dynamics of inflation.

First, we will show how the learning mechanism can account for the slow moving increase in inflation even when only few shocks are considered. Specifically, we will show that two events could be central to understand the two spurs of inflation of the '70s. The first one coincides with the first reference to the "Great Society" made by President Johnson in May 1964. We model this as a large shock to the long term component of government expenditure. The second shock is President Ford's tax cut in the mid-'70s .

We modify our basic calibration in two dimensions. First, we make the learning process substantially slower making the short lasting and long lasting PM/AF persistences more similar. Second, we increase the relative a-priori probability of moving to the long lasting PM/AF higher and decrease the persistence of the virtuous regime. This second change does not play any role in explaining the high inflation of the '70s but it helps in explaining the risk of deflation faced by the US economy in the late '90s and early 2000's as the result of the large primary surpluses during those years. The underlying intuition goes as follows.

Making the long lasting PM/AF more likely determines a "contamination effect" on the virtuous regime, with the result that even under such a regime fiscal shocks have some effect on the level of inflation. These effects are mild, given that the relative probability is still small, but not negligible. We then consider the following parameterization for the transition matrix:

$$H = \begin{bmatrix} .9200 & .0720 & .0080 \\ .0600 & .9400 & \\ .0050 & & .9950 \end{bmatrix}$$

These values imply that it takes quite a long time for agents to get *convinced* that they entered a non-Ricardian world. Specifically, τ^* is in this case equal to 110 quarters, implying that it takes more than 27 years for agents to be sure that they live in a long lasting PM/AF regime. On the other hand, agents are a-priori relatively worried about the possibility of entering this world: Following the first deviation, agents attach a $p_{13}/(p_{12} + p_{13}) = 10\%$ probability to having entered the long lasting PM/AF regime. Therefore, even when the virtuous regime is in place, agents are so concerned about the possibility of entering the long lasting PM/AF regime that high debt implies inflationary pressure.

The simulation is started using the smoothed estimates for the DSGE states obtained by Bianchi and Ilut (2011).⁹ Figure 9 reports the simulated values for inflation, expenditure, and tax revenues. The black solid vertical lines mark the two key events that are used to explain the increase in trend inflation of the '70s. We assume that the a switch from the virtuous regime to the PM/AF regime with the first reference to the Great Society plans. We use the results of Bianchi and Ilut (2011) to pin down the switch from the PM/AF to the virtuous regime, occurring in mid-1980, a few quarters after the appointment of Volcker (August 1979).

Several aspects of this simulation are worth being mentioned. First, following the *Great Society shock*, inflation starts to rise, but very smoothly. In the short run, such low frequency movements are probably hard to detect. Second, by the time the 'Ford's tax cut' shock hits, inflation has already gained some momentum due to the acceleration in agents' pessimism. Agents are now more pessimistic about the possibility of a quick return to the virtuous regime. Consequently, inflation rises faster following this second fiscal shock. Third, the switch to the virtuous regime determines a sudden drop in inflation as agents' beliefs about the future behavior of policy makers are subject to a drastic swing. Fiscal shocks are now largely sterilized as agents revise their expectations about the way the debt will be financed.

⁹A fully specified estimation exercise is on our research agenda, but at this stage it is unfeasible as it takes a long time to solve a MS-DSGE model with hundreds of regime.

However, as explained above, because agents are still worried about the possibility of a regime change and expenditure is still high, inflation does not go back to the steady level. Instead, it stabilizes on a larger value that reflects the deviation of government debt from its own steady state. Finally, the large primary surpluses of the '90s determine a smooth and persistent decline in inflation that gets dangerously close to zero. This feature is again linked to the fact that even when the economy is under the virtuous regime, agents are concerned about the size of debt. As the debt gets largely reduced, inflation expectations decline accordingly.

Summarizing, in this Section we have taken an historical perspective to show how dormant shocks can be used to explain low frequency movements in the process for inflation. An important lesson is that it might take a long time to see significant effects of these shocks on inflation and a false sense of security might pervade policy makers. We have also shown how, with appropriate assumptions on the transition matrix H , it is possible to generate a contamination effect from the inflationary regime to the virtuous regime. This allowed us to link the low inflation of the late '90s early 2000s to the large primary surpluses run by the Clinton administration.

6 ...to find out the Future

What are the consequences of the previous analysis for the current situation? Is the US economy heading toward a prolonged period of high inflation? Should policy makers feel reinsured that long term interest rates and inflation expectations seem to be under control? In order to answer these questions we will consider a series of forecasts conditional on different scenarios on the policy makers' behavior.

6.1 Basic scenarios: No announcements about the exit strategy

In this subsection we consider two benchmark simulations that are characterized by different transition matrices H . Policy makers announce that the economy will be at the zero-lower-bound for one year. We approximate such an announcement using a third regime that has the same characteristics of the PM/AF regime, but for which the response to the output gap is set to zero. We believe this is a convenient and potentially appropriate way to model the zero-lower-bound, given that the Central Bank would probably react if inflation started rising substantially.

For each simulation, we consider two alternative scenarios. In the first one, the zero-lower-bound period is followed by the PM/AF policy, while in the second case the virtuous policy

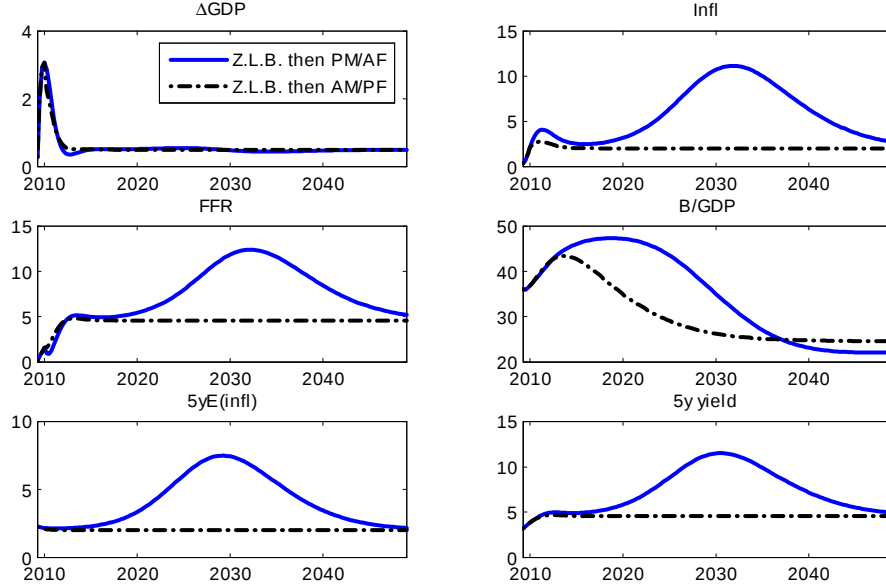


Figure 10: Conditional forecasts based on a transition matrix that implies high reputation of policy-makers in preventing large fluctuations in inflation. The zero-lower-bound is announced for one year. After that, two scenarios are considered: Always PM/AF or always AM/PF. In both cases, no announcement is made about the exit strategy from the zero-lower-bound. Five year ahead inflation expectations and the 5-year yield are computed taking into account the possibility of regime changes.

mix prevails. Furthermore, we assume that policy makers do not make any announcement regarding the exit strategy, so agents do not know how the economy will evolve after the zero-lower-bound period. Therefore, it is very important to specify what agents expect is going to happen once the deviation is over. We assume that in the last period of the announced deviation, the probability that agents attach to going back to the virtuous regime is equal to the one that would prevail if they had observed one year of PM/AF policy. Notice that agents anticipate that this is the way they will think one year from the time of the announcement. This assumption is not of secondary importance, as it will become clear in the examples that we will consider later on.

For each simulation, we compute the path for 5-year ahead inflation expectations and the 5-year interest rate. Both of them are computed taking into account the possibility of regime changes using the methods developed in Bianchi (2011).

The first conditional forecast assumes a transition matrix that implies a high level of

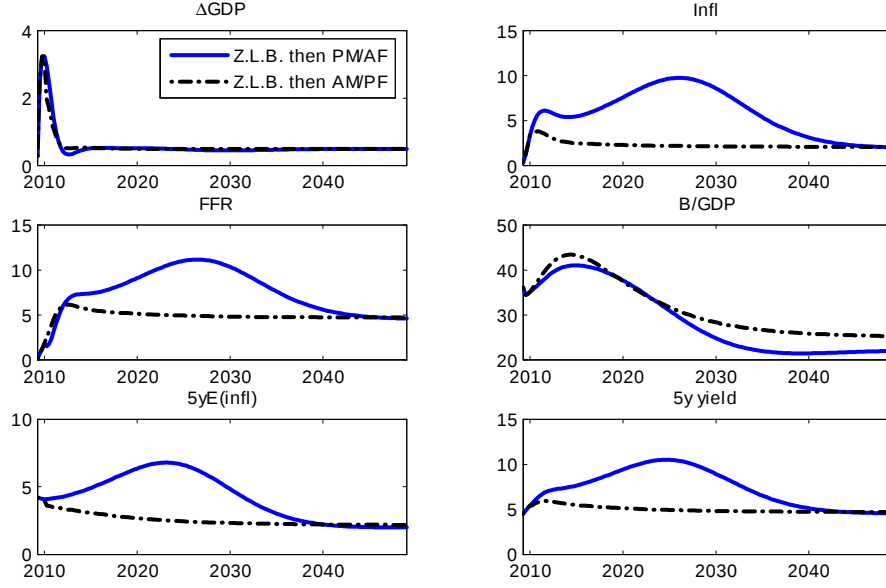


Figure 11: Conditional forecasts based on a transition matrix that implies low reputation of policy-makers in preventing large fluctuations in inflation. The zero-lower-bound is announced for one year. After that, two scenarios are considered: Always PM/AF or always AM/PF. In both cases, no announcement is made about the exit strategy from the zero-lower-bound. Five year ahead inflation expectations and the 5-year yield are computed taking into account the possibility of regime changes.

reputation for the monetary/fiscal policy mix:

$$H = \begin{bmatrix} .9750 & .0249 & .0001 \\ .0800 & .9200 & \\ .0100 & & .9900 \end{bmatrix}$$

The a-priori beliefs that agents assign to a long lasting deviation is very low, .4%, and agents tolerate relatively long deviations as the ratio p_{22}/p_{33} is relatively high. Therefore it takes more than ten years for agents to get convinced that they entered a long lasting period of PM/AF policy ($\tau^* = 129$).

Figure 10 reports the results. The first aspect that is worth noting is that long term inflation expectations are initially very well anchored independently of the behavior of policy makers. In a similar fashion, the five year yield is very low, in line with what is observed in the data. This is because even if the PM/AF policy mix prevails, agents are initially optimistic about the probability of moving back to the virtuous combination. However, as time goes by, the behavior of policy makers starts making a difference. If they insist in following the

flipped regime combination, agents get increasingly convinced that the economy entered a long lasting period of PM/AF policy mix. Accordingly, inflation and inflation expectations start drifting. Eventually inflation gets to levels that are comparable to the ones observed in the '70s. If instead the virtuous policy mix is in place, this pattern is absent, as agents observe taxes being raised in order to stabilize debt. In both cases, GDP growth experiences an acceleration in the short run that reflects the fact that the economy is going back to the steady state. However, while under the virtuous policy combination output does not move any further, if the PM/AF policy mix prevails, we observe very low frequency movements in growth that reflect the slow revision in agents beliefs. Interestingly, the first spur of inflation that is associated with the recovery dies out very quickly, with the result that an external observer could be induced to think that the central bank has still full control of inflation dynamics. But this is just an illusion, as the run-up of inflation that follows makes clear.

These conditional forecasts highlight the risks associated with trying to infer the risk of high inflation looking at current inflation expectations or long term interest rates. If it takes time for agents to learn about the nature of the deviation that they are currently experiencing, than their expectations are likely to be initially very well anchored. This is likely to be especially true for an economy like the US that, as suggested by Woodford (cite) has experienced a prolonged period of monetary dominated policy mix. In such an economy, the a-priori beliefs about the possibility of entering a long lasting deviation are arguably very low. Furthermore, it is worth pointing out that short lasting interventions that do not resolve the long run problems of debt sustainability cannot be interpreted as changes in policy mix. These are only shocks that do not move agents' beliefs about the resolution of the long term sustainability of government debt.

Figure 11 conducts the same exercise using the transition matrix of Section 5. As explained before, this transition matrix assumes that even under the virtuous regime, agents are concerned about the possibility of switching to the long lasting PM/AF regime. From a qualitative point of view the results are similar to the ones obtained before. However, inflation expectations are higher at the beginning of the simulation.

The difference between the two simulations can be interpreted in two ways. Policy makers might have in fact more credibility than what is implied by this second simulation and more in line with the first transition matrix. As explained before, the model considered here could be extended to have a progressive change in agents' beliefs about the persistence of the virtuous regime. In that case, a prolonged period of AM/PF would have the consequence of convincing agents that a long lasting PM/AF deviation is quite unlikely, rationalizing the parameter choices made for the first simulation. Alternatively, we could imagine that during the current crisis, agents have become more willing to hold government bonds because of a

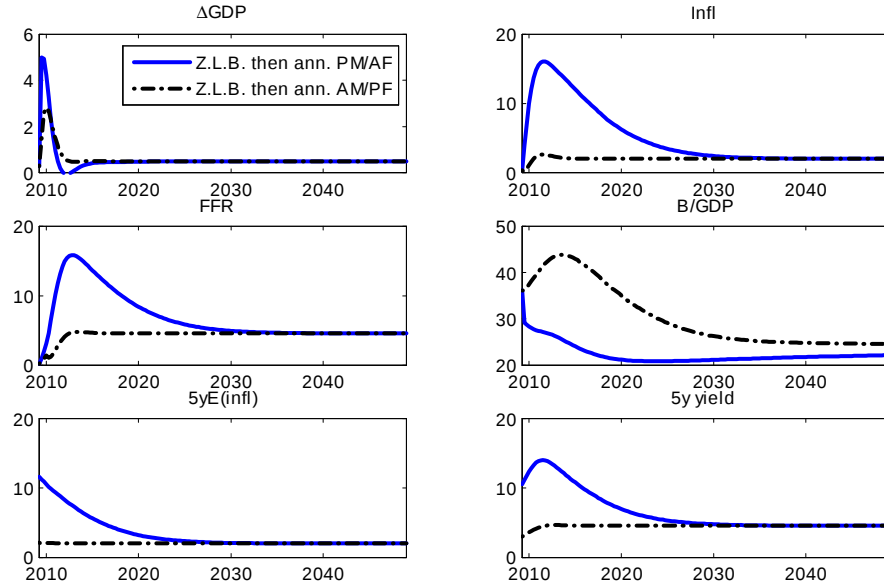


Figure 12: Conditional forecasts based on a transition matrix that implies high reputation of policy-makers in preventing large fluctuations in inflation. The zero-lower-bound is announced for one year. After that, two scenarios are considered: Always PM/AF or always AM/PF. In both cases, the exit strategies are announced and are fully credible. Five year ahead inflation expectations and the 5-year yield are computed taking into account the possibility of regime changes.

"flight to quality" effect, as it has been suggested by Cochrane (2011). Such a change in preferences would have the important effect of lowering the expected burden of debt and would keep inflation expectations low even if agents find a switch to the long lasting PM/AF regime quite likely. Future versions of this paper will explore these alternative explanations in more detail.

6.2 Coordinated announcements

Since the beginning of the Great Recession, policy makers have been intervening very heavily in the economy. The Federal Reserve and the Bush and Obama administrations have in most of the cases tried to coordinate their actions. At the same time, the monetary and fiscal authorities don't seem to have reached the same level of coordination in announcing an exit strategy. In what follows, we will show that such a lack of coordination might explain why the policy interventions do not seem to have delivered significant effects.

Figure 12 considers two opposite announcements regarding the policy mix that will prevail after the zero-lower-bound period. In the first case (solid blue line) the economy will enter

a prolonged period of PM/AF policy. In the second case (dashed black line) the virtuous regime will prevail. In both cases agents firmly believe the announcements made by the policy makers. It is easy to see that the consequences of the two announced policies are completely different. When policy makers commit to entering a long lasting deviation into the PM/AF regime, inflation starts increasing immediately, real interest rates drop, and the economy experiences a boom. At the same time, the debt-to-GDP ratio declines substantially. This is the result of three events: The increase in output, the drop in real interest rates, and a change in the value of long term bonds in response to the upward revision in short term interest rates. None of these effects occurs when agents *know* that the economy will enter the virtuous regime. Output grows, but this is simply the result of the economy going back to the steady state, with the result that the losses experienced during the Great Recession are never reabsorbed.

The model considered here does not have the necessary complexity to capture all aspects of the current crisis. However, the key message that arises would likely survive in richer models: It is not enough to announce a prolonged period of zero interest rates to give an extra boost to the economy. What matters is what agents expect is going to happen after such a period. Announcing a prolonged period of PM/AF policy would change things, but at the cost of very high inflation, something that the Federal reserve is not willing to accept. So far policy makers have not being able to resolve agents' uncertainty about the future. Given that it might take a long time for agents to decide that a prolonged deviation to the PM/AF regime is ahead of them, we should not expect much from large fiscal interventions given that agents are likely to expect an increase in taxes.

Fernandez-Villaverde et al. (2011) also point out the role of fiscal uncertainty in slowing down the recovery during the current crisis. In their case, government debt is always backed by future surpluses. However agents are uncertain about the timing of the budgetary adjustments and the choices of the fiscal instruments (i.e. taxation or expenditure cuts). An interesting extension for future research would consist in integrating the two approaches, especially considering the change in volatility that derives from entering a long lasting period of PM/AF policy.

6.3 Contradictory statements

In this last subsection we will show how the lack of coordination could become even more dangerous in the moment that the signals that policy makers send to the public become contradictory, something that is not far from happening in the current economic and political climate.

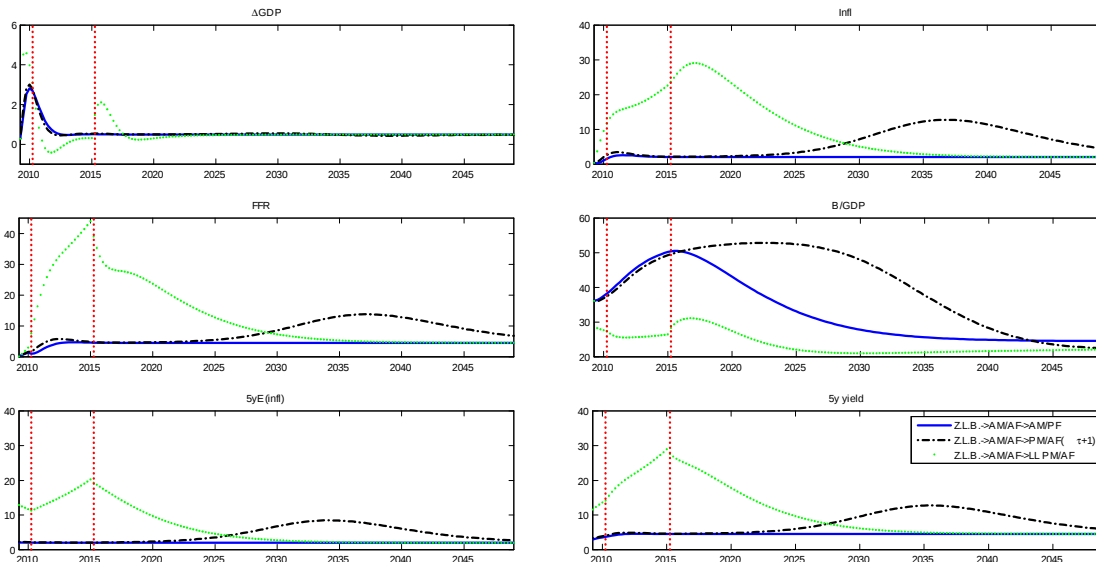


Figure 13: Conditional forecasts based on a transition matrix that implies high reputation of policy-makers in preventing large fluctuations in inflation. The zero-lower-bound is announced for one year. Then five years of AM/AF regime follows. After that, three scenarios are considered: Always AM/PF, always PM/AF with learning, long lasting PM/AF. In all of the three cases, agents correctly anticipate the events. Five year ahead inflation expectations and 5-year yield are computed taking into account the possibility of regime changes.

In recent years the Fed has repeatedly tried to make clear 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 government suggest that future increases in taxes will not be large enough to balance the fiscal budget. According to what we have seen so far these two "signals" are not consistent. The Fed cannot control inflation if the fiscal authority is not committed 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. In this section we analyze this scenario, showing that things could go terribly wrong.

When taken in isolation, a regime in which both authorities are active implies no solution. To see why, suppose that inflation is above the target and that the Federal reserve tries to push it down by increasing the FFR more than one to one in response to the observed deviation. This determines an increase in the real interest rate, a contraction in output and

consequently an acceleration in the debt-to-GDP ratio. This would require an increase in taxation, but agents know that this is not going to happen. 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 stable 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 consider three scenarios. In all of them, the Fed announces that interest rates will be kept near zero for a year. To implement the 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 an AM/AF regime with persistence equal to .9. The three scenarios differ in terms of agents' beliefs regarding which authority will eventually prevail. In the first case, we assume that the economy will enter the virtuous regime, while in the second and third simulations the fiscal authority will prevail. However, in the second scenario agents do not take a stance on the nature of the deviation to the PM/AF regime and the learning process starts as if agents had observed five periods of PM/AF policy (the current one plus the four quarters associated with the initial zero-lower-bound deviation). Instead, in the third simulation agents interpret the fact that the monetary authority accommodates the behavior of the fiscal authority as a signal that the latter will be the dominant authority.

Figure 13 reports the results. We shall start with the scenario in which agents expect the monetary authority to prevail (solid blue line). In this case debt keeps accumulating for some years, given that the fiscal authority is not adjusting taxes to stabilize debt, but there are no effects on output and inflation as agents understand that eventually taxes will be raised and debt will be repaid. Therefore, in this case the contradictory signals are not problematic. The dashed black line considers the case in which agents expect the fiscal authority to prevail, but they are "agnostic" about the nature of this deviation. Once again we do not observe any effect on inflation and output in the short run as agents are still confident that in the long run taxes will be raised. However, as policy makers engage in a long series of deviations, agents become progressively more pessimistic and inflation starts rising.

The last case is the most interesting one (dotted green line). Now agents anticipate that the fiscal authority will eventually prevail and that this will inaugurate a prolonged period of fiscal dominance. During the first year, under the zero lower bound, debt drops on impact and inflation jumps as agents understand that taxes will never be raised. At the same time, the economy experiences sustained growth because of the negative real interest rates. Inflation expectations and long term interest rates reflect the expectation that inflation will

be high in the future. This is in part due to the fact that debt will be financed through inflation. However, this basic channel is exacerbated because agents expect a conflict between the two policy authorities. After the zero-lower-bound period, the monetary authority tries to push inflation down, causing a recession (notice how GDP growth is below the steady state). However, agents believe that the fiscal authority will eventually prevail. Therefore, the increase in real interest rates has the perverse effect of generating even more inflation through the expectation channel. This creates a vicious circle that brings inflation and nominal interest rates to become larger and larger. Finally, after five years, the monetary authority gives up. We then observe a short run increase in the debt-to-GDP ratio as agents' expectations about future short term interest rates are revised downward. The real interest rate becomes negative, growth accelerates and then goes back to the steady state. At the same time inflation keeps increasing for a couple of years and then goes back to the steady state in *twenty* years.

7 Conclusions

When combining regime changes with a learning mechanism the strict distinction between Ricardian and non-Ricardian regimes typical of the Fiscal Theory of Price Level literature breaks down. In its stead, a continuum of regimes reflecting agents' beliefs about the future behavior of policy makers arises. As agents observe more and more deviations from a virtuous regime in which the Fed has full control of inflation, they become increasingly convinced that inflation will have to increase in order to stabilize the debt-to-GDP ratio. This implies that the law of motion characterizing the economy evolves over time in response to what agents observe. Therefore, the model is able to generate a run-up in inflation as relatively optimistic agents become more and more pessimistic.

We introduced the notion of dormant shocks. These are shocks that move the debt-to-GDP ratio and that have no effects on the macroeconomic variables when policy makers behave according to a virtuous regime. However, as policy makers start deviating from such a regime and agents become more and more discouraged about the possibility of moving back to the virtuous regime, the effects of the dormant shocks arise, with a progressive movement in inflation and an increase in uncertainty.

We have put the theory to work to explain the evolution of inflation in the US as the result of a series of key events. First, the *high* and *accelerating* inflation of the '70s is explained by a progressive deterioration of agents' beliefs and two important fiscal shocks: The announcement of the Lyndon Johnson's Great Society Initiatives and Ford's tax cuts. Second, the sudden drop of the early '80s is the result of a regime change coinciding with

the appointment of Volcker. Third, we link the risk of deflation in the late '90s to Clinton's primary surpluses.

Finally, we used the model to make a series of important points about the current situation. First, low inflation expectations and low long term interest rates are likely to reflect the reputation US policy makers have built over the years. This means that the true risk of inflation might be higher than what it appears and crucially related to the way policy makers will behave in the future. Second, simply announcing a long period of very low interest rates is not likely to have any significant impact on growth. Announcing a long lasting deviation from the virtuous regime would. However, the remarks made by the Federal Reserve seem to go in the opposite direction, given that the Chairman Bernanke has repeatedly stated that inflation will be kept on target. Third, a lack of coordination between the fiscal and monetary authority could lead to disastrous outcomes if agents were to anticipate a prolonged conflict between the two authorities.

References

- Atkeson, A., Chari, V. and Kehoe, P.: 2009, Sophisticated monetary policies, *Quarterly Journal of Economics* **125**(1), 47–89.
- Barro, R. J.: 1974, Are government bonds net wealth?, *Journal of Political Economy* **82**(6), 1095–1117.
- Benati, L.: 2008, Investigating inflation persistence across monetary regimes, *The Quarterly Journal of Economics* **123**(3), 1005–1060.
URL: <http://ideas.repec.org/a/tpr/qjecon/v123y2008i3p1005-1060.html>
- Bernanke, B. S. and Mihov, I.: 1998, Measuring monetary policy, *Quarterly Journal of Economics* **113**(3), 862–902.
- Bianchi, F.: 2011, Methods for Markov-switching models, Duke University, working paper.
- Bianchi, F. and Ilut, C.: 2011, Monetary/Fiscal Policy Mix and Agents’ Beliefs, Duke University, working paper.
- Bianchi, F. and Melosi, L.: 2011, Learning about regime changes, Duke University, working paper.
- Canova, F. and Gambetti, L.: 2004, On the time variations of US monetary policy: Who is right?, *Money Macro and Finance (MMF) Research Group Conference 2004 96*, Money Macro and Finance Research Group. available at <http://ideas.repec.org/p/mmfc/mmfc04/96.html>.
- Chib, S.: 1996, Calculating posterior distributions and model estimates in markov mixture models, *Journal of Econometrics* **75**, 79–97.
- Clarida, R., Gali, J. and Gertler, M.: 2000, Monetary policy rules and macroeconomic stability: Evidence and some theory, *Quarterly Journal of Economics* **115**, 147–180.
- Cochrane, J. H.: 1998, A frictionless model of U.S. inflation, in B. S. Bernanke and J. J. Rotemberg (eds), *NBER Macroeconomics Annual 1998*, MIT Press, Cambridge, MA, pp. 323–384.
- Cochrane, J. H.: 2001, Long term debt and optimal policy in the fiscal theory of price level, *Econometrica* **69**, 69–116.
- Cochrane, J. H.: 2011, Understanding policy in the Great Recession: Some unpleasant fiscal arithmetic, *European Economic Review* **55**, 2–30.
- Cogley, T., Primiceri, G. and Sargent, T. J.: 2008, Inflation-gap persistence in the u.s, *AEJ Macroeconomics* . forthcoming.
- Cogley, T. and Sargent, T. J.: 2005, The conquest of American inflation: Learning and robustness to model uncertainty, *Review of Economic Dynamics* **8**, 528–563.
- Cogley, T. and Sargent, T. J.: 2006, Drifts and volatilities: Monetary policies and outcomes

- in the post WWII U.S., *Review of Economic Dynamics* **8**, 262–302.
- Cogley, T., Sargent, T. J. and Surico, P.: 2011, The return of the gibson paradox. mimeo.
- Coibion, O. and Gorodichenko, Y.: 2011, Monetary policy, trend inflation, and the great moderation: An alternative interpretation, *American Economic Review* **101**(1), 341–370.
- Davig, T. and Doh, T.: 2008, Changes in inflation persistence: Lessons from estimated markov-switching new keynesian models, Federal Reserve Bank of Kansas City, mimeo.
- Davig, T. and Leeper, E. M.: 2006, Fluctuating macro policies and the fiscal theory, *NBER Macroeconomics Annual* 2006 pp. 247–298.
- Davig, T. and Leeper, E. M.: 2007, Generalizing the Taylor principle, *American Economic Review* **97**(3), 607–635.
- Eusepi, S. and Preston, B.: 2011, The maturity structure of debt, monetary policy and expectations stabilization, Journal of the European Economic Association, forthcoming.
- Farmer, R. E. A., Waggoner, D. and Zha, T.: 2010, Minimal state variable solutions to markov-switching rational expectations models, Federal Reserve Bank of Atlanta, mimeo.
- Favero, C. and Monacelli, T.: 2005, Fiscal policy rules and regime (in)stability: Evidence from the U.S., IGIER-Bocconi University working paper.
- Fernandez-Villaverde, J., Kuester, K., Guerrón-Quintana, P. and Rubio-Ramirez, J. F.: 2011, Fiscal volatility shocks and economic activity, working paper.
- Fernández-Villaverde, J. and Rubio-Ramírez, J. F.: 2007, How structural are structural parameters, *2007 NBER Macroeconomics Annual* .
- Fernández-Villaverde, J., Rubio-Ramírez, J. F. and Guerrón-Quintana, P.: 2010, Fortune or virtue: Time-variant volatilities versus parameter drifting in u.s. data, *working paper* .
- Hall, G. J. and Sargent, T. J.: 2010, Interest rate risk and other determinants of post-WWII u.s. government debt/gdp dynamics, NYU working paper.
- Hamilton, J. D.: 1989, A new approach to the economic analysis of nonstationary time series and the business cycle, *Econometrica* **57**, 357–384.
- Ireland, P.: 2007, Changes in the federal reserve’s inflation target: Causes and consequences, working paper.
- Justiniano, A. and Primiceri, G.: 2008, The time varying volatility of macroeconomic fluctuations, *American Economic Review* **98**(3), 604–41.
- Kim, C.-J. and Nelson, C. R.: 2004, Estimation of a forward-looking monetary policy rule: A time-varying parameter model using ex-post data, *Journal of Monetary Economics* **53**(8), 1949–1966.
- Leeper, E. M.: 1991, Equilibria under active and passive monetary and fiscal policies, *Journal of Monetary Economics* **27**, 129–147.
- Leeper, E. M. and Zha, T.: 2003, Modest policy intervention, *Journal of Monetary Eco-*

- nomics* **50**, 1673–1700.
- Liu, Z., Waggoner, D. and Zha, T.: 2008, Sources of the Great moderation: Shocks, frictions, or monetary policy?, Federal Reserve Bank of Atlanta, mimeo.
- Lubik, T. and Schorfheide, F.: 2004, Testing for indeterminacy: An application to U.S. monetary policy, *American Economic Review* **94**(1), 190–217.
- Primiceri, G.: 2005, Time varying structural vector autoregressions and monetary policy, *The Review of Economic Studies* **72**(3), 821–852.
- Primiceri, G.: 2006, Why inflation rose and fell: Policymakers’ beliefs and US postwar stabilization policy, *The Quarterly Journal of Economics* **121**(August), 867–901.
- Sargent, T. and Wallace, N.: 1981, Some unpleasant monetarist arithmetic, *Federal Reserve Bank of Minneapolis Quarterly Review* **Fall**, 1–17.
- Sargent, T., Williams, N. and Zha, T.: 2006, Shocks and government beliefs: The rise and fall of American inflation, *American Economic Review* **96**(4), 1193–1224.
- Schorfheide, F.: 2005, Learning and monetary policy shifts, *Review of Economic Dynamics* **8**(2), 392–419.
- Sims, C. A.: 1994, A simple model for study of the determination of the price level and the interaction of monetary and fiscal policy, *Economic Theory* **4**, 381–399.
- Sims, C. A.: 2009, Stepping on a rake: The role of fiscal policy in the inflation of the 1970’s, Princeton University, working paper.
- Sims, C. A. and Zha, T.: 2006, Were there regime switches in US monetary policy?, *American Economic Review* **91**(1), 54–81.
- Stock, J. H. and Watson, M. W.: 2003, Has the business cycle changed? evidence and explanations, Presented at Monetary Policy and Uncertainty: Adapting to a Changing Economy, Federal Reserve Bank of Kansas City Symposium, Jackson Hole, Wyoming.
- Woodford, M.: 1994, Monetary policy and price level determinacy in a cash-in-advance economy, *Economic Theory* **4**, 345–389.
- Woodford, M.: 1995, Price level determinacy without control of a monetary aggregate, *Carnegie-Rochester Series of Public Policy* **43**, 1–46.
- Woodford, M.: 2001, Fiscal requirements of price stability, *Journal of Money, Credit, and Banking* **33**, 669–728.