

Dormant Shocks and Fiscal Virtue*

Francesco Bianchi

Leonardo Melosi

Duke University

London Business School

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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. The model accounts for the variability of the link between inflation and fiscal imbalances across time and countries. Dormant fiscal shocks can account for the run-up of US 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 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. 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 primary surpluses 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 the Virtuous regime, with the fiscal authority not reacting to debt fluctuations and the Central Bank disregarding the Taylor principle, two situations can arise. If agents expect the return to the Virtuous regime to be close enough in time, inflation stability is preserved. On the other hand, if the deviation is expected to last for a long period of time, high levels of debt require an increase in inflation.

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 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 fiscal imbalance 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.

Therefore, our theoretical framework is able to account for the instability of the link between fiscal discipline and inflation. In our model, agents are fully rational, but uncertain about the way the trade-off between inflation and taxation will be resolved. This creates a continuum of regimes indexed according to agents' beliefs and a smooth transition from the law of motion that prevails under the Virtuous regime to the one that characterizes a long lasting deviation. Therefore, the strict distinction between Ricardian and non-Ricardian regimes typical of the Fiscal Theory of Price Level literature (Leeper (1991), Sims (1994), Woodford (1994, 1995, 2001), and Cochrane (1998, 2001)) breaks down and is replaced by a series of intermediate

regimes that reflect the evolution of agents' expectations about the future conduct of fiscal and monetary policies.¹

Furthermore, agents *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 (2010), 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. Instead, 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 (2010) 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 effects arise because agents might erroneously regard bonds as net-wealth as in Barro (1974). Instead, in this paper non-Ricardian effects arise in the moment fully rational agents become discouraged about debt stability being guaranteed by movements in primary surpluses.

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 or taxation would trigger the inflationary mechanism.

We illustrate the key properties of the model using the basic three equations new-Keynesian model used by Clarida et al. (2000) and Lubik and Schorfheide (2004) augmented with a fiscal block. We then conduct a quantitative analysis using a richer model borrowed from Bianchi and Ilut (2012). We first analyze the progressive unfolding of the US Great Inflation: Inflation started increasing in the mid-60s, gained momentum in the early '70s, got out of

¹See 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.

control towards the end of that same decade, and experienced a sudden drop in the early '80s. We show that such pattern can be explained by the evolution of the monetary/fiscal policy mix, as argued in Bianchi and Ilut (2012). 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, 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.

We then 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 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 close to 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 announcements 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.

Our paper is related to the extensive literature that explores the evolution of output and inflation over the past sixty years using microfounded models. 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 changes in the volatility of investment shocks play a key role in explaining the evolution of the reduced form properties of the economy. ? and ? allow for heteroskedasticity and changes in monetary policy. Finally, Ireland (2007), Liu et al. (2011), and Schorfheide (2005) consider models in which the target for inflation is moving over time. Our model is able to account for changes in the low frequency component of inflation and in the volatility of the endogenous variables.

Our work is also related to Benati (2008), Cogley et al. (2010), Cogley et al. (2011), and Coibion and Gorodichenko (2011). Benati (2008) documents that inflation persistence is not stable across time and across countries. Cogley et al. (2010) study changes in the persistence of the inflation gap measured in terms of short- to medium-term predictability. Cogley et al. (2011) show that the Gibson’s paradox, i.e. low correlation between inflation and nominal interest rates, vanished during the Great Inflation and reappeared after 1995. 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. Our model is able to generate variability in the persistence and low frequency component of inflation as a result of the evolution of agents’ beliefs about the future behavior of policy makers.

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 6 and 7 put the theory at work: First looking at the past, then looking at the future. Section 8 concludes.

2 The Model

In order to illustrate the key properties of the model, we consider the basic new-Keynesian model employed by Clarida et al. (2000) and Lubik and Schorfheide (2004) augmented with a fiscal rule. This model has very little built-in persistence, given that it features a purely forward looking Phillips curve. This will allow us to isolate the effects of the learning mechanism.

2.1 A new-Keynesian model

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

$$\pi_t = \beta E_t(\pi_{t+1}) + \kappa(y_t - z_t) \tag{1}$$

$$y_t = E_t(y_{t+1}) - (R_t - E_t(\pi_{t+1})) + (1 - \rho_d) d_t \tag{2}$$

$$d_t = \rho_d d_{t-1} + \sigma_d \epsilon_{d,t}, \quad \epsilon_{d,t} \sim N(0, 1) \tag{3}$$

$$z_t = \rho_z z_{t-1} + \sigma_z \epsilon_{z,t}, \quad \epsilon_{z,t} \sim N(0, 1) \tag{4}$$

where all variables are expressed in percentage deviations from the steady state or, in the case of output, from a trend path. The process z_t , captures exogenous shifts of the marginal costs of production and can be interpreted as a supply shock. The process d_t summarizes changes in

preferences and other demand side disturbances other than government purchases (see below). Inflation dynamics are described by the expectational Phillips curve (1) with slope κ . This relation can be derived assuming a quadratic adjustment cost or Calvo pricing. Equation (2) is an intertemporal Euler equation describing the households' optimal choice of consumption and bond holdings. The parameter $\beta = 1/(1+r^*) < 1$ is the households' discount factor, where r^* is the steady state net real interest rate.

The linearized government budget constraint is given by:

$$b_t = \beta^{-1}b_{t-1} + b\beta^{-1}(R_{t-1} - \pi_t - \Delta y_t) - s_t \quad (5)$$

where b_t and s_t represent debt and surplus in terms of GDP and in linear deviations from the steady state and b is the steady state debt-to-GDP ratio. We assume that the government only moves lump sum taxes and provides a subsidy. In other words, we exclude government purchases and we assume that the primary surplus coincides with net lump sum taxes. This will allow us to completely isolate the effects of fiscal shocks deriving from the lack of fiscal discipline. Introducing government expenditure would not modify the mechanism outlined here, but would make the interpretation of the results less immediate. The federal fiscal authority moves the primary surplus according to the rule:

$$s_t = \rho_s s_{t-1} + (1 - \rho_s) \delta_{b,\xi_t} b_{t-1} + \sigma_s \epsilon_{s,t}, \quad \epsilon_{s,t} \sim N(0, 1) \quad (6)$$

while the Central Bank moves the FFR according to the rule:

$$R_t = \rho_{R,\xi_t} R_{t-1} + (1 - \rho_{R,\xi_t}) (\psi_{\pi,\xi_t} \pi_t + \psi_{y,\xi_t} [y_t - z_t]) + \sigma_R \epsilon_{R,t}, \quad \epsilon_{R,t} \sim N(0, 1) \quad (7)$$

The central bank responds to deviations of inflation and output from their respective target levels, while the fiscal authority responds to deviations of debt from its own steady state. The unobserved state ξ_t captures 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 H .

2.2 Fixed coefficients and determinacy regions

Before describing the features of the model with regime changes, it is useful to review the properties of its *fixed coefficient* counterpart. Following Leeper (1991), we can distinguish four regions of the parameter space according to existence and uniqueness of a solution to the model. These regions are summarized in Table 1 and in general they are a function of all parameters of the model. However, in practice, the two policy rules are key in determining

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

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

existence and uniqueness of a solution. There are two determinacy regions. The first one (Active Monetary/Passive Fiscal (AM/PF)) is the most familiar one: The Taylor principle is satisfied and the fiscal authority moves taxes in order to keep debt on a stable path: $\psi_\pi > 1$ and $\delta_s > \beta^{-1} - 1$. To grasp the intuition behind this result, substitute the tax rule in the law of motion for government debt (assuming for simplicity $\rho_s = 0$) and isolate the resulting coefficient for lagged government debt:

$$b_t = (\beta^{-1} - \delta_b) b_{t-1} + b\beta^{-1} (R_{t-1} - \pi_t - \Delta y_t) - \sigma_s \epsilon_{s,t}$$

Intuitively, in order to guarantee stability of government debt, we need this coefficient to be smaller than one ($\beta^{-1} - \delta_b < 1$), so that debt is mean reverting. This in turn requires the coefficient on debt in the tax rule to satisfy the condition $\delta_b > \beta^{-1} - 1$. Therefore, we can think of fiscal policy as passive to the extent that it *passively* accommodates the behavior of the monetary authority ensuring debt stability. Woodford (1995) refers to this regime combination as Ricardian in the sense that the fiscal authority is committed to making the necessary adjustments to fiscal tools in order to neutralize any disturbance affecting the government budget constraint. We will refer to this policy combination as Virtuous regime.

The second determinacy region (Passive Monetary/Active Fiscal (PM/AF)) is less familiar and corresponds to the case in which the fiscal authority is not committed to stabilizing the process for debt: $\delta_b(\xi_t) < \beta^{-1} - 1$. Now it is the monetary authority that *passively* accommodates the behavior of the fiscal authority, disregarding the Taylor principle and allowing inflation to move in order to stabilize the process for debt: $\psi_\pi(\xi_t) < 1$. Woodford (1995) refers to this regime combination as non-Ricardian. Under this regime, even in the absence of distortionary taxation, shocks to net taxes can have an impact on the macroeconomy as agents understand that they will not be followed by future offsetting changes in the fiscal variables. Finally, when both authorities are active (AM/AF) no equilibrium exists, whereas when both of them are passive (PM/PF) the economy is subject to multiple equilibria.

As it will be highlighted in the next section, this one-to-one mapping between the regions of the parameter space identified by Leeper (1991) and the terminology introduced by Woodford (1995) applies only in the context of a model with fixed coefficients. When regime changes are introduced the distinction between Ricardian and non-Ricardian regimes becomes more subtle and crucially depends on agents' beliefs about the future evolution of the policy mix.

The profession has extensively studied the behavior of the economy under the AM/PF regime and the problem of indeterminacy, whereas less attention has been devoted to the PM/AF determinacy region. A popular argument is based on the idea that even if the government does not constantly move taxes in order to stabilize debt, this 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 want to allow for the possibility that if a deviation lasts for a prolonged period of time, agents can rightfully lose confidence about the commitment of the government to stabilize debt. In Section 3.1, we start building the intuition using a model in which agents can exactly infer the likely duration of a deviation from the Virtuous regime. 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 (1)-(7) 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, $\psi_{\pi,1} = \psi_{\pi}^A > 1$ and $\delta_{b,1} = \delta_b^P > \beta^{-1} - 1$). Under Regime 2, the central bank reacts less than one-for-one to inflation and the fiscal authority does not move surpluses in response to movements in government debt (i.e. monetary policy is passive and fiscal policy is active, $\psi_{\pi,2} = \psi_{\pi}^P < 1$ and $\delta_{b,2} = \delta_b^A = 0 < \beta^{-1} - 1$). To capture the idea that these deviations are short lasting, we

Parameter	Value	Parameter	Value	Parameter	Value
ψ_{π}^A	0.80	ρ_s	0.90	$100\sigma_R$	0.20
ψ_{π}^P	2.00	ρ_z	0.90	$100\sigma_s$	0.50
ψ_y^A	0.10	ρ_d	0.90	$100\sigma_z$	0.70
ψ_y^P	0.10	b	1.00	$100\sigma_d$	0.40
ρ_R^A	0.75	κ	0.05	p_{11}	0.95
ρ_R^P	0.75	β	0.99	p_{12}	0.495
δ_b^A	0			p_{22}	0.70
δ_b^P	0.03			p_{33}	0.99

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

set the persistence of Regime 2 to a relatively low value: $p_{22} \ll 1$.

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: $\psi_{\pi,3} = \psi_{\pi,2} = \psi_{\pi}^P < 1$, $\delta_{b,3} = \delta_{b,2} = \delta_b^A = 0 < \beta^{-1} - 1$, 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 a long lasting deviation represents 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, i.e. they are more likely to move to Regime 2: $p_{12} > p_{13}$.

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 values reported in Table 2. 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 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):

$$S_t = T(\xi_t, \theta, H) S_{t-1} + R(\xi_t, \theta, H) \varepsilon_t \quad (8)$$

It is worth emphasizing that the law of motion of the DSGE states depends on the model 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.

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 a negative primary surplus 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 adjusting primary surpluses in response to the increase in debt. Under the long lasting PM/AF regime the debt-to-GDP ratio experiences a sudden drop, due to the increases in inflation and GDP, followed by a smooth return to the steady state from below because of the increased level of expenditure and the slowdown in growth.

From these impulse responses, it should be clear that a short lasting deviation from Virtuous regime has very different implications with respect to a long lasting deviation. The interesting fact here is that the behavior of the two authorities is *identical* across the two regimes. However, the two regimes differ to the extent that they induce different expectations about the future policy makers' behavior. 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. Therefore, under the short lasting deviation agents are confident that in the near future the government will run a sequence of primary surpluses to balance the debt-to-GDP ratio. Instead, when a long lasting deviation occurs, agents are discouraged about a prompt return to the Virtuous regime and the fiscal imbalance calls for an increase in inflation. Given that the Taylor principle does not hold, the monetary accommodates such an increase. This determines a drop in real interest rates and output increases. High inflation and the jump in output cause the drop in the debt-to-GDP ratio.

Agents' expectations also affect the response of the economy to the other shocks. The first row reports the responses to a monetary policy shock. Under all regimes, the Federal Reserve

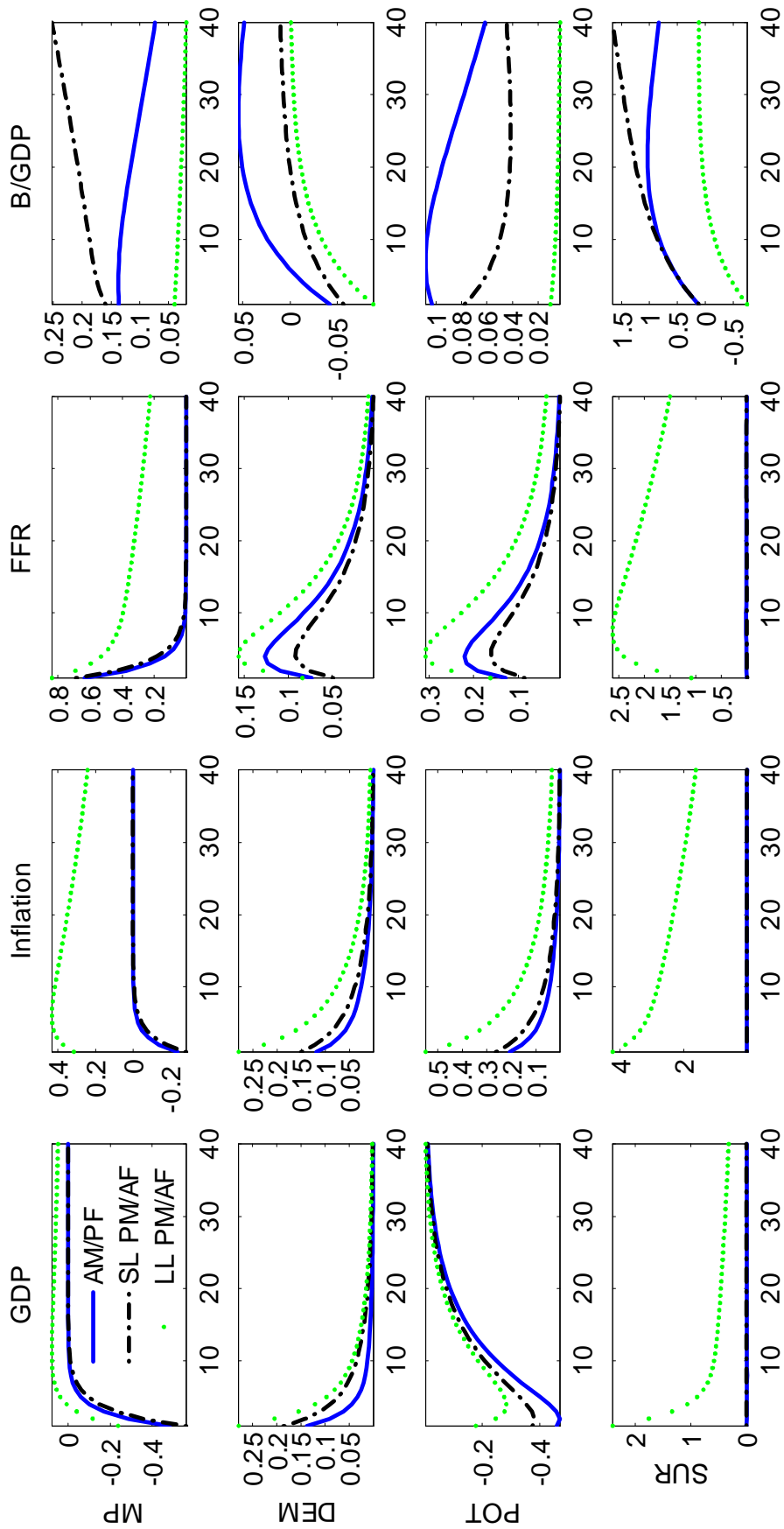


Figure 1: Impulse responses under perfect information.

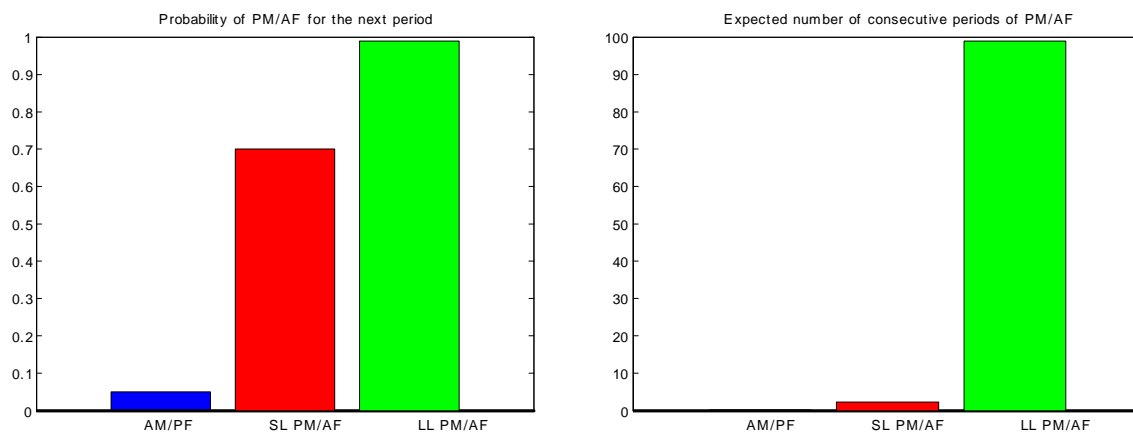


Figure 2: The two columns report respectively the one-step-ahead probability of entering a period of PM/AF policy and the expected number of consecutive periods of PM/AF under the different regimes assuming that agents have perfect information.

retains the ability to generate a recession. However, under the long lasting PM/AF regime, inflation instead of declining, increases. This "stepping on a rake" effect (Sims (2011)) implies that the Central Bank loses its ability of controlling inflation the moment that its actions are not adequately supported by the fiscal authority. Notice that the inflation dynamics under the short lasting PM/AF regime are very similar to the ones implied by the Virtuous regime. This occurs despite the fact that the fiscal 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. In the short run, given the presence of nominal rigidities, the increase in the FFR determines an increase in the real interest that makes the cost of debt larger. Under the short lasting deviation, agents are confident that a return to the Virtuous regime will soon occur. This is why the increase in debt is not inflationary. Under the long lasting deviation agents anticipate that the government will not increase primary surpluses in the near future and inflation increases in order to stabilize debt. The Central Bank accommodates the increase of inflation and debt slowly declines because of negative real interest rates.²

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 policies in the medium and long run. When agents are confident about a prompt return to the virtuous policy mix, a fiscal imbalance is not inflationary even if policy makers do not immediately take care of it. Agents understand

²The stepping on a rake effect is a robust finding and it holds also in the richer model considered by Bianchi and Ilut (2012). However, the short run inflation dynamics can differ depending on the exact features of the model.

that with high probability the necessary adjustments will occur in the future. Instead, when the regime change is perceived to be too far into the future, inflation will have to move in order to guarantee debt stability.

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 agents' information set. 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 conduct Bayesian learning in order to infer the regime that they are in. Regime changes are modeled as the three-regime Markov switching process described above. In this context, the transition matrix also reflects agents' priors about the evolution of the monetary/fiscal policy mix.³

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. However, while the Virtuous regime is fully revealing, when the PM/AF mix prevails agents do not know whether the short-lasting Regime 2 or the long-lasting Regime 3 is in place. Agents have to learn the nature of the deviation 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 alternative policy mix.* 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

$$\text{prob} \{s_{t+1} \neq 1 | \mathcal{F}_t\} = \frac{p_{22} (p_{12}/p_{13}) (p_{22}/p_{33})^{\tau-1} + p_{33}}{(p_{12}/p_{13}) (p_{22}/p_{33})^{\tau-1} + 1}. \quad (9)$$

The probability $\text{prob} \{s_{t+1} \neq 1 | \mathcal{F}_t\}$ 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 increasing with respect to the number of last consecutive deviations τ . 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

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 can be derived by applying Bayes' theorem and then combining the resulting probabilities with the transition matrix H . See Bianchi and Melosi (2011) for a detailed derivation.

the two authorities 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:

$$\lim_{\tau \rightarrow \infty} \text{prob} \{s_{t+1} \neq 1 | \mathcal{F}_t\} = p_{33} \quad (10)$$

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

$$p_{33} - \text{prob} \{s_{t+1} \neq 1 | \tau = \tau^*\} < \varepsilon \quad (11)$$

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 (9) 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 are not able to tell if they entered a long lasting or a 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 convinced that the economy entered the long-lasting PM/AF regime. Since the short lasting regime is characterized by lower persistence, 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 substantially 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'

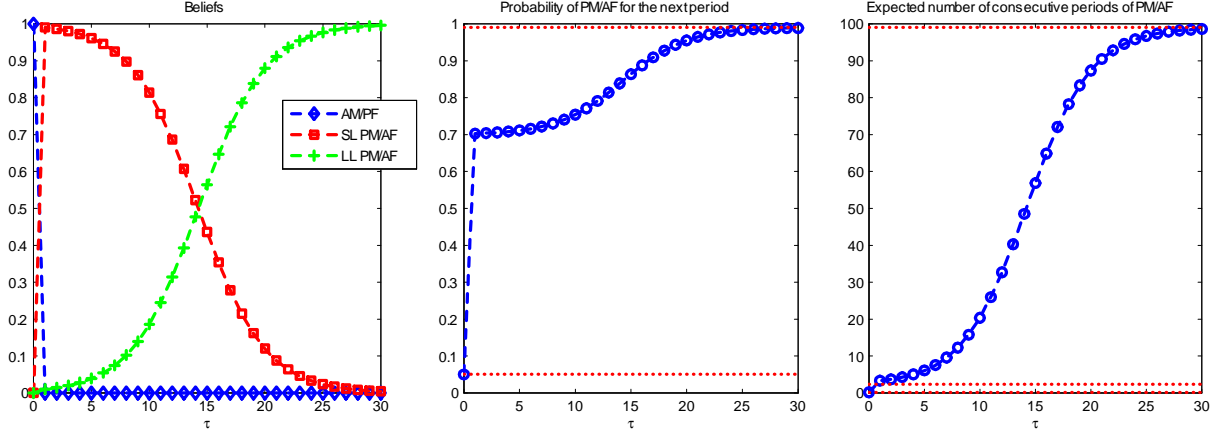


Figure 3: From left to right, the three columns describe, as a function of the number of consecutive deviations τ , the evolution of agents' beliefs, the one-step-ahead probability of observing the PM/AF policy mix, and the expected number of consecutive deviations.

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. Initially the probability attached to the long lasting PM/AF regime increases slowly, but it eventually accelerates as agents from relatively optimistic become relatively pessimistic. 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 on we will show that this drift in beliefs about the future behavior of policy makers has deep implications for the way shocks propagate through the economy. However, first we will briefly describe the solution method for the model with learning.

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 policies 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

⁵It is not hard to extend the model to allow for a short lasting and a long lasting AM/PF regime. Bianchi and Melosi (2011) consider this case.

the endogenous variables in the model with learning cannot be fully captured by the three policy regimes. Instead, agents expect different dynamics for next period's endogenous variables depending on their beliefs 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 with learning described above can be recasted in terms of an expanded set of $(\tau^* + 1) > 3$ new regimes, where $\tau^* > 0$ is defined by the condition (11). The increased number of regimes captures the degree of pessimism associated with observing deviations from the Virtuous regime for $\tau = 1 \dots \tau^*$ periods. The $\tau^* + 1$ regimes are given by:

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

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

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

Hence, one can recast the Markov-switching DSGE model with learning 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 methods developed to solve Markov-switching rational expectations models.

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. However, they are uncertain about the future behavior of policy makers and this uncertainty has important consequences for the law of motion of the economy.

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 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 that agents become certain that they entered a long lasting deviation ($\tau = \tau^*$). The law of motion would change again if agents were to observe a return to the Virtuous regime. This case will be analyzed in the Section 6.

Fiscal shocks. We shall start considering the responses to a negative primary surplus shock when agents have observed a large number of consecutive deviations. In this case, agents are already 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 the shock, inflation increases immediately and then it slowly declines. At the same time, the debt-to-GDP ratio experiences a large drop as a result of higher growth and larger inflation, despite the increase in the primary deficit. As it was the case for the perfect information case, these dynamics reflect the expectation that the government will not increase future surpluses in order to cover the current deficits.

When the starting number of deviations is low, these effects are initially mitigated because agents are confident about a prompt return to the Virtuous regime. During the first few

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.

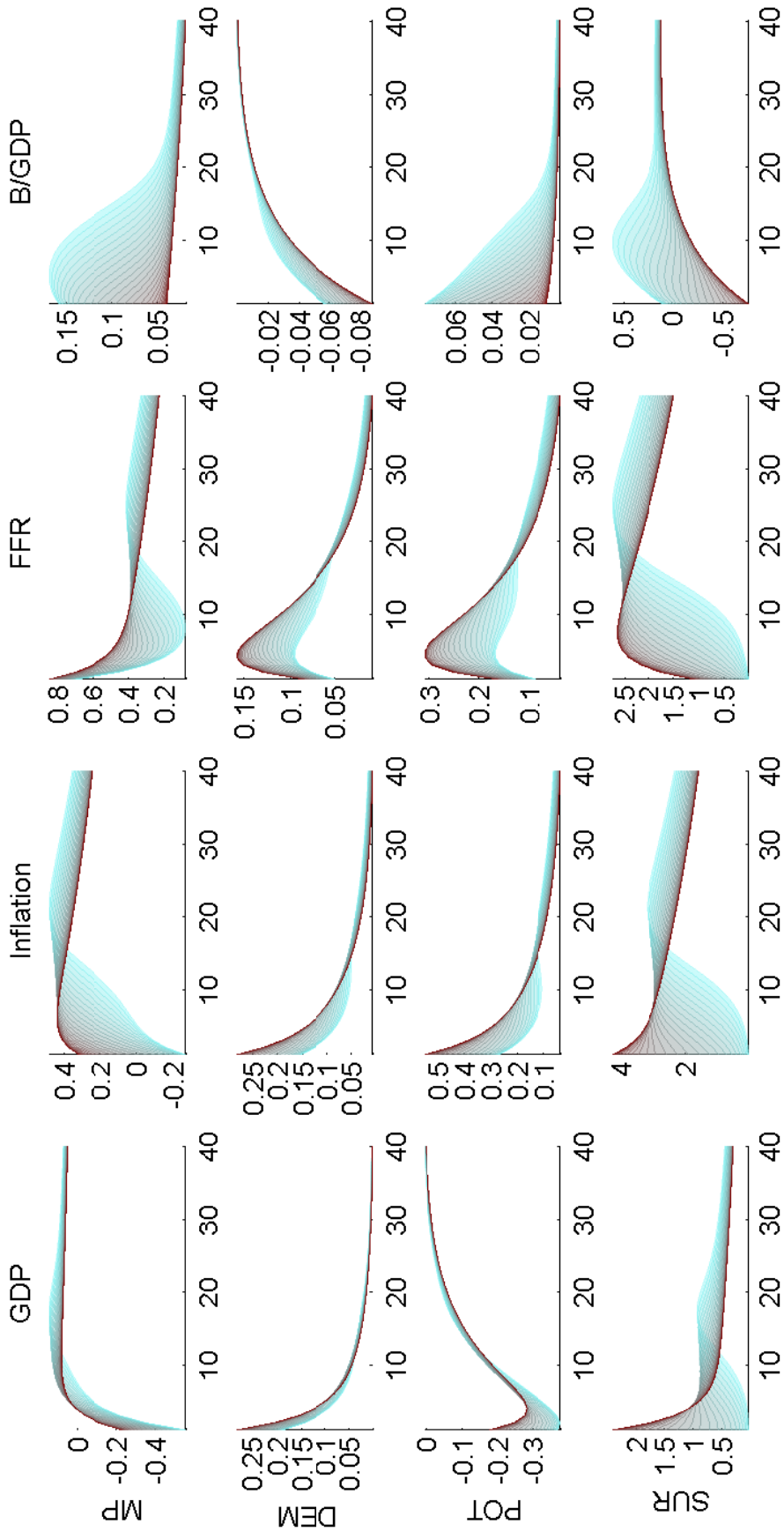


Figure 4: Impulse responses under learning assuming that the PM/AF regime prevails over the relevant horizon. Moving from the light-blue to the dark-red, the initial number of observed deviations increases. The impulse responses under the AM/PF are very similar, although not identical, to the ones that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

periods, inflation and GDP barely move, even if the current behavior of policy makers is still characterized by the PM/AF policy mix. Consequently, we do not observe the drop in the debt-to-GDP ratio, that instead starts increasing because of the primary deficits. However, as agents observe more and more deviations, their expectations start drifting, the law of motion evolves, and the non-Ricardian dynamics start arising. Inflation starts increasing smoothly, then it accelerates in the moment that agents become relatively pessimistic, and it finally reaches its peak after approximately seven years. Symmetrically, real interest rates decline because the Taylor principle does not hold, output starts growing, 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. However, as agents become aware of the possibility that the economy entered a long lasting deviation, inflation starts increasing and 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 immediately increases. These dynamics have two important implications. First, when the initial number of deviations is small, a central bank might be initially induced to believe that it is still able to control inflation, 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 a fiscal shock is particularly interesting, given that the learning mechanism can substantially prolong its effects and move the peak of the responses further into the future. In this section, we will analyze these features more in detail introducing the notion of *dormant shocks* and characterizing their effects as a function of *fiscal virtue*.

4.1 Dormant shocks

Figure 5 considers a large negative shock to primary surpluses 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

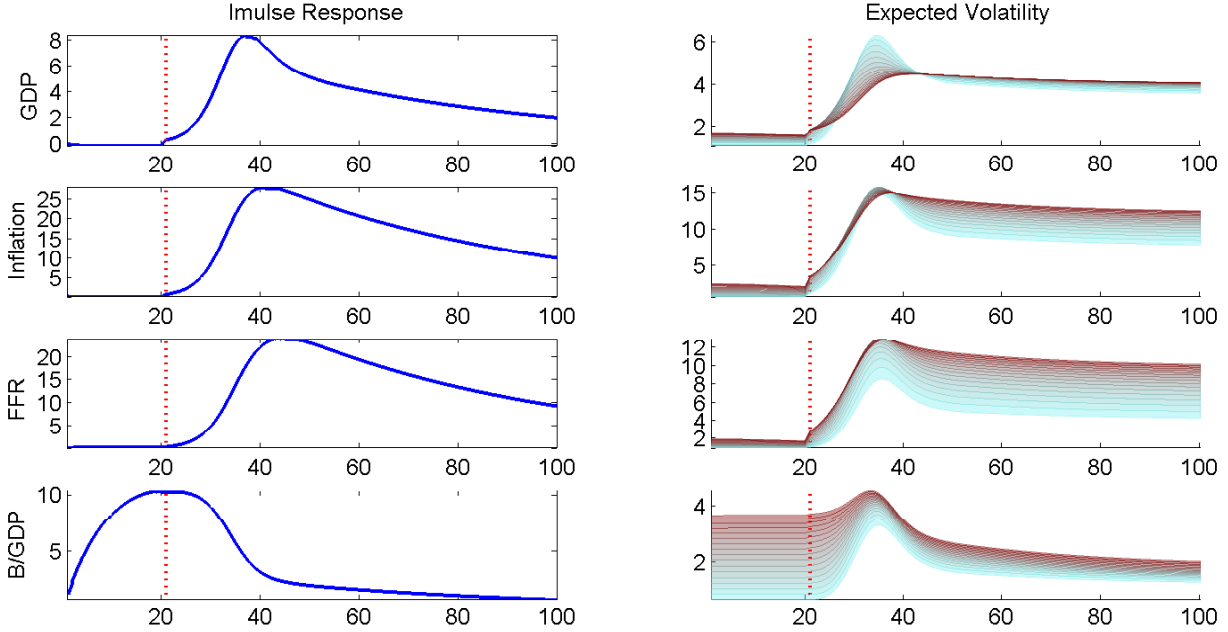


Figure 5: The two columns report the evolution of the endogenous variables and the correspondent expected volatilities assuming a large primary surplus shock occurring at time 0 and a regime change from the AM/PF to the PM/AF regime after five years. In the right column, moving from the light blue to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

changes and the evolution of agents' beliefs. For a variable X_t and an horizon T , it corresponds to the square root of $V(X_{t+T}|\mathcal{F}_t)$.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 macroeconomic 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 occurred. 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

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

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 volatilities of the macroeconomic variables start increasing smoothly and reach a peak in the moment that agents from relatively optimistic become relatively pessimistic. These beliefs coincide with the peak of uncertainty because agents attach similar probabilities to two very different scenarios: A large spur of inflation to cover the large debt or a return to the Virtuous regime with a subsequent drop in inflation. This also explains why uncertainty is *larger* at short horizons than at long horizons: In the long run debt is expected to be closer to the steady state, independently of the path taken by policy makers, while in the short run the large stock of debt can have pervasive effects on the macroeconomy. 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 long as the economy is under the Virtuous regime.

As agents become convinced that debt will be inflated away, the volatilities approach the values associated with the long lasting PM/AF regime. Under this regime macroeconomic uncertainty is larger than under the Virtuous regime for three reasons. 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 fiscal shocks that are neutral under the Virtuous regime, affect the macroeconomic variables under the long lasting PM/AF.

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 an increase in inflation that seems to gain momentum over time. Our external observer would probably conclude that the target for inflation has changed and that the volatility of the exogenous shocks has increased.

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

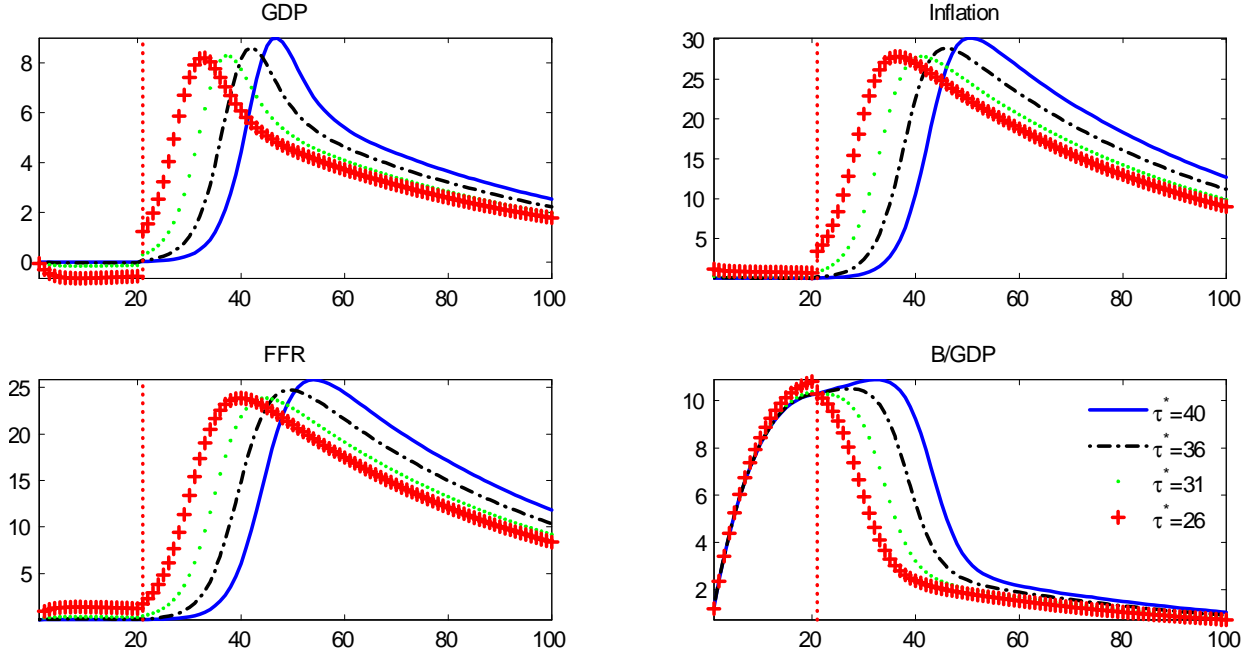


Figure 6: The figure considers the effects of large a "dormant shock" to primary surplus for transition matrices that differ according to the a-priori relative probability of a short lasting deviation. The shock occurs at time 0, while the regime change occurs after 20 periods (red vertical bar). The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

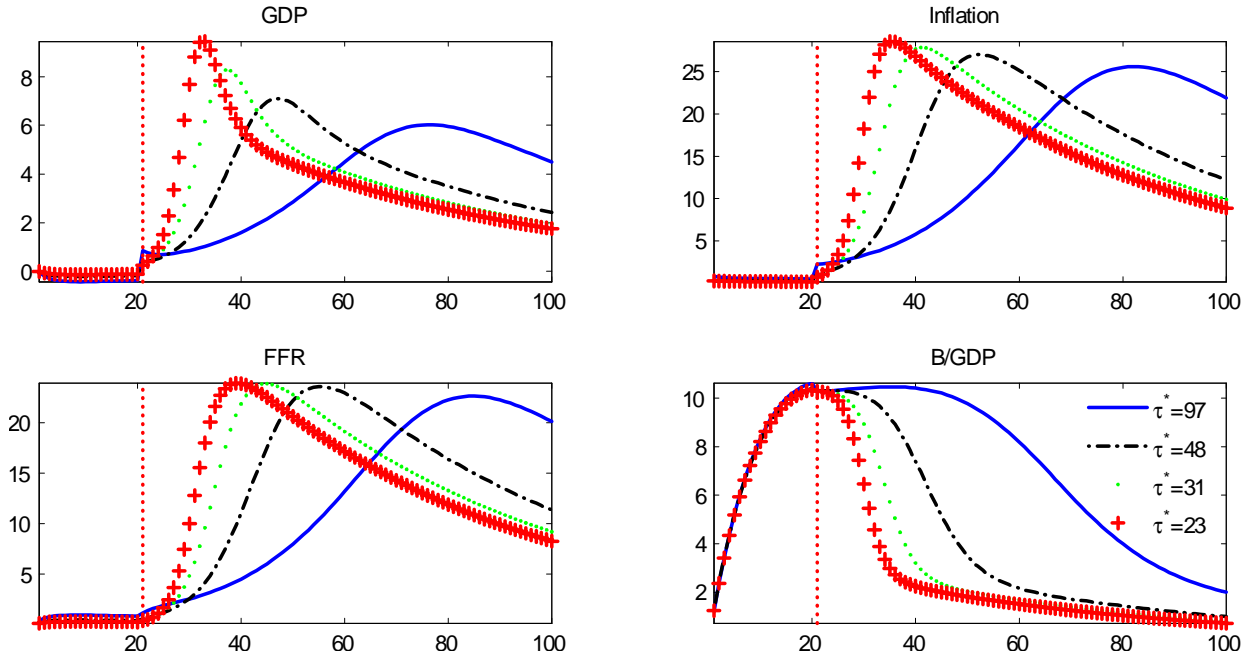


Figure 7: The figure considers the effects of a large "dormant shock" to primary surplus for transition matrices that differ according to the relative persistence of the two PM/AF regimes. The shock occurs at time 0, while the regime change occurs after 20 periods (red vertical bar). The different a-priori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

$100p_{13}/(p_{12} + p_{13})$	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.

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. Given that the ratio $p_{13}/(p_{12} + p_{13})$ controls a-priori agents' beliefs, it is capturing the credibility of policy-makers in agents' eyes. Agents' beliefs could be 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 agents form subjective conjectures about how likely it is that the government will engage in a persistent deviation from the Virtuous regime. In other words, agents could retain the occurrence of a long lasting deviation to the PM/AF regime more or less likely according to policy makers' reputation. For example, 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, *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.

Fiscal Virtue can make 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 long lasting deviation. 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.

5 Extended Model

In this second part of the paper we conduct a quantitative analysis based on a richer model augmented with external habits, government purchases, inflation indexation to past inflation, a maturity structure for government debt, and a richer fiscal block in which government expenditure and taxation are modeled separately. The model and the parameter estimates are taken from Bianchi and Ilut (2012). Bianchi and Ilut (2012) estimate a DSGE model subject to a structural break from a PM/AF to an AM/PF regime in order to explain the rise and fall of US inflation. Here we expand the number of regimes to allow for a short lasting and a long lasting PM/AF regime and introduce the learning mechanism.

To facilitate the interpretation of the results, we combine the law of motion of the model variables with a system of observation equations including variables that often enter the economic debate. We reconstruct the following observables: real GDP growth rate, annualized quarterly inflation, annualized quarterly FFR, and debt to GDP ratio on a quarterly basis. Appendix A contains an accurate description of the model, the parameter values, and impulse responses under perfect information and learning.

6 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 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. Following Bianchi and Ilut (2012), 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 choose a transition matrix in order to satisfy two criteria. 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

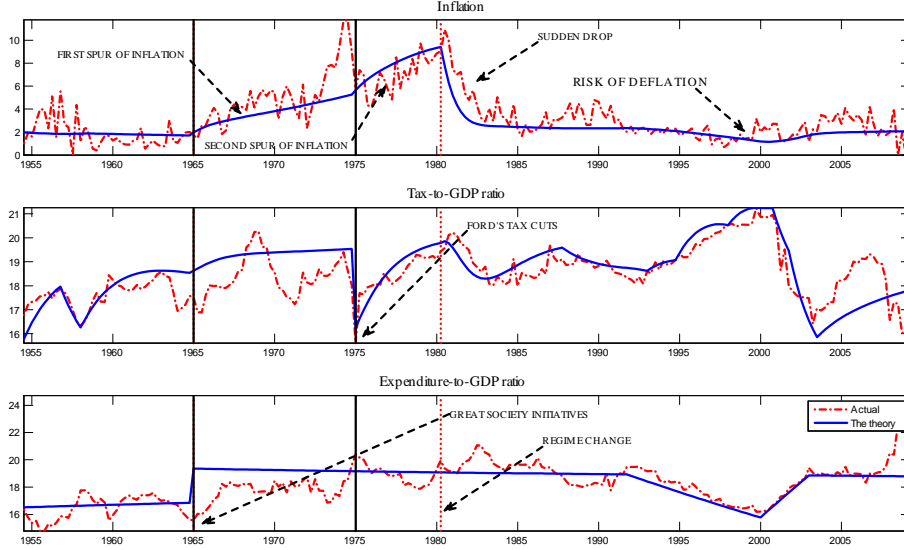


Figure 8: The figure shows the results for a simulation meant to illustrate the properties of the model with learning. Four events are key. First, a large shock to the long term component of expenditure and a switch from the AM/PF to the PM/AF regime assumed to coincide with the first reference to the 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.

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 regime: 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 (2012).⁹ Figure 8 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 there is 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 (2012) 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 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. 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.

7 ...to find out the Future

After having shown that the model can account for the events of the past, we now move to analyzing 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

⁹A fully specified estimation exercise is on our research agenda, but at this stage it is unfeasible.

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. 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).

7.1 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 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.

The first conditional forecast assumes a transition matrix that implies a high level of 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 9 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 PM/AF 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 (2011), 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 10 conducts the same exercise using the transition matrix of Section 6. 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

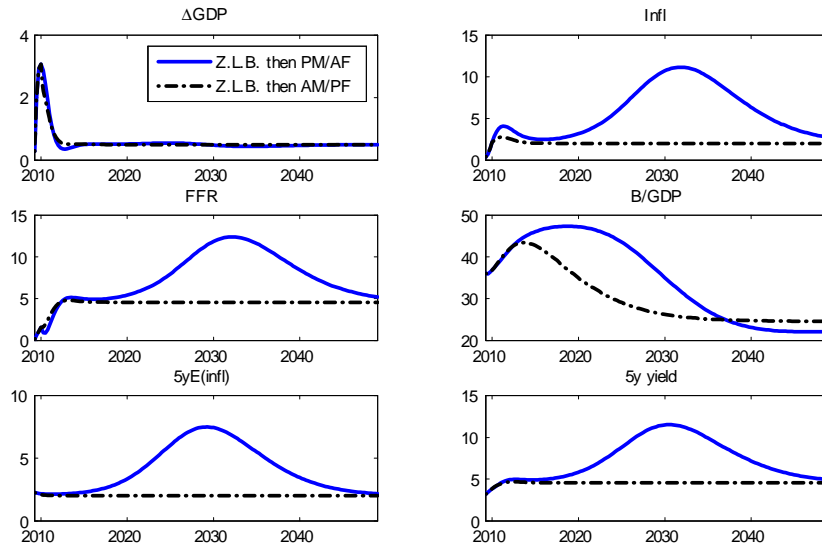


Figure 9: Conditional forecasts based on a transition matrix that implies high reputation of policy-makers in preventing large fluctuations in inflation. The zero-lower-bound is announced for one year. After that, two scenarios are considered: Always PM/AF or always AM/PF. In both cases, no announcement 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.

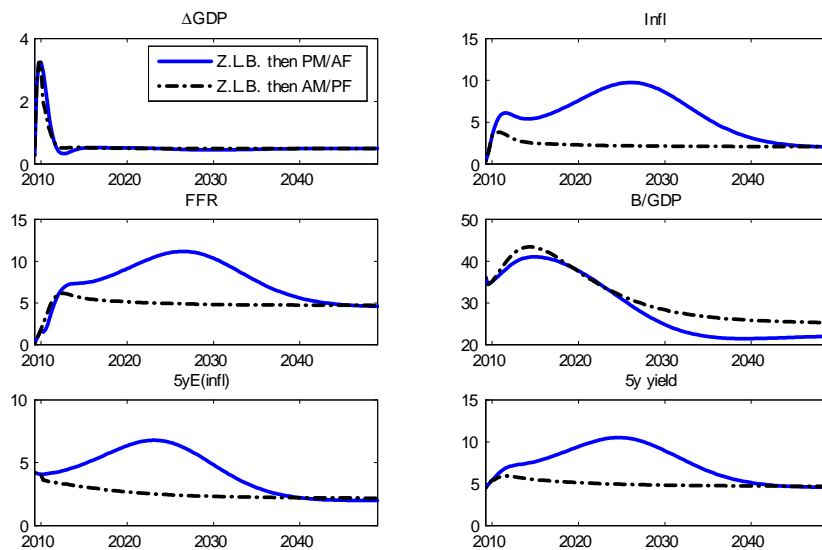


Figure 10: Conditional forecasts based on a transition matrix that implies low reputation of policy-makers in preventing large fluctuations in inflation. The zero-lower-bound is announced for one year. After that, two scenarios are considered: Always PM/AF or always AM/PF. In both cases, no announcement 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.

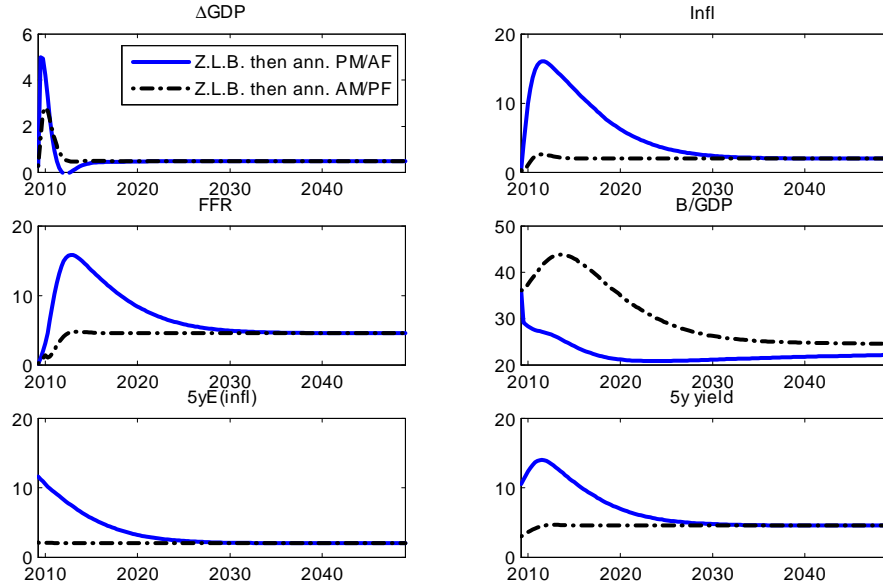


Figure 11: Conditional forecasts based on a transition matrix that implies high reputation of policy-makers in preventing large fluctuations in inflation. The zero-lower-bound is announced for one year. After that, two scenarios are considered: Always PM/AF or always AM/PF. In both cases, the exit strategies 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.

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 "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.

7.2 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 11 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, implying 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 survive in richer models: It is not enough to announce a prolonged period of low 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 been 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.

7.3 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.

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

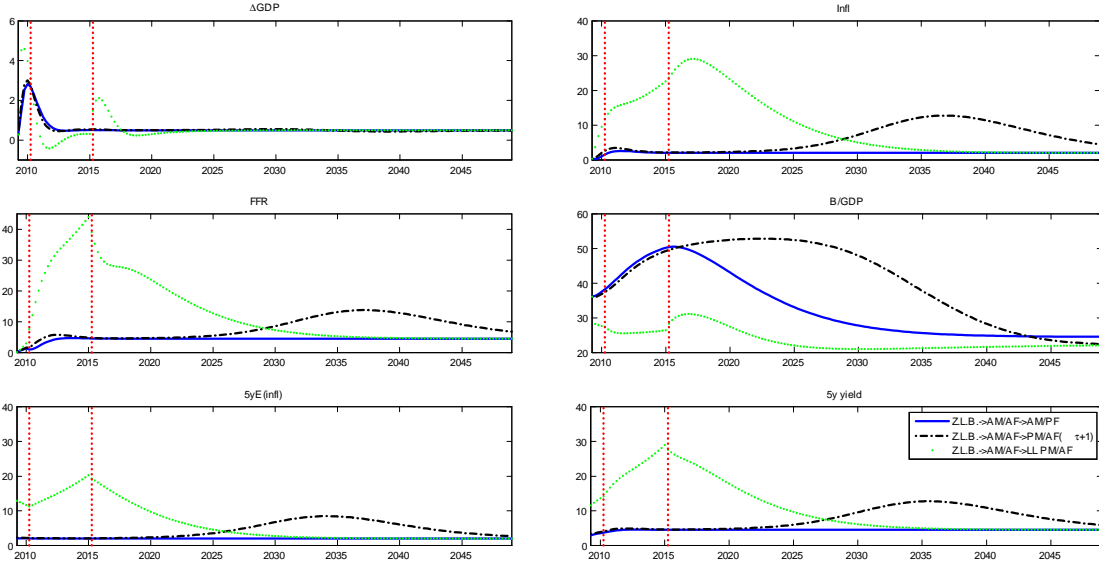


Figure 12: Conditional forecasts based on a transition matrix that implies high reputation of policy-makers in preventing large fluctuations in inflation. The zero-lower-bound is announced for one year. Then five years of AM/AF regime follows. After that, three scenarios are considered: Always AM/PF, 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 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 12 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, implying a change in the price of long term bonds. 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.

8 Conclusions

When agents are uncertain about the way debt will be repaid 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 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.

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A Extended model

In this appendix we describe the model used in the quantitative analysis of Section 6 and Section 7. The model is taken from Bianchi and Ilut (2012).

A.1 Model description

Households. The representative household maximizes the following utility function:

$$E_0 \left[\sum_{s=0}^{\infty} \beta^s e^{d_s} \left[\log (C_s - \Phi C_{s-1}^A) - h_s \right] \right] \quad (12)$$

subject to the budget constraint:

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

where D_t stands for real dividends paid by the firms, C_t is consumption, P_t is the aggregate price level, h_t is hours, W_t is the real wage, $N T_t$ stands for net taxes, and C_t^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 zero and time series representation: $d_t = \rho_d d_{t-1} + \sigma_d \varepsilon_{d,t}$. In line with Cochrane (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. News about future surpluses can then translate into smooth changes in inflation, as opposed to a discrete jump in the current price level, even in absence of any additional friction. Hall and Sargent (2011) show that revaluation effects explain a significant fraction of the fluctuations of the debt-to-GDP ratio. Following Eusepi and Preston (2010) and Woodford (2001), we assume that there are two types of government bonds: one-period government debt, B_t^s , in zero net supply with price P_t^s and a more general portfolio of government debt, B_t^m , in non-zero net supply with price P_t^m . The former debt instrument satisfies $P_t^s = R_t^{-1}$. The latter debt instrument has payment structure $\rho^{T-(t+1)}$ for $T > t$ and $0 < \rho < 1$. The 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 faces a downward-sloping demand curve:

$$Y_t(j) = (P_t(j)/P_t)^{-1/v_t} Y_t \quad (13)$$

where the parameter $1/v_t$ is the elasticity of substitution between two differentiated goods.¹⁰

¹⁰Shocks to the elasticity of substitution v_t imply shocks to the markup $mu_t = 1/(1 - v_t)$. We define the

The firms take as given the general price level, P_t , and the level of real activity, Y_t . Whenever a firm changes its price, it faces quadratic adjustment costs represented by an output loss:

$$AC_t(j) = .5\varphi (P_t(j)/P_{t-1}(j) - \Pi_{t-1})^2 Y_t(j) P_t(j)/P_t \quad (14)$$

where $\Pi_t = P_t/P_{t-1}$ is gross inflation at time t .

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

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

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

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

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

where $P_t^m B_t^m$ is the market value of debt and T_t and E_t represent federal tax revenues and federal expenditures, respectively. The term TP_t is a shock that is meant to capture a series of features that are not explicitly modeled here, such as changes in the maturity structure and the term premium. This shock is necessary to avoid stochastic singularity when estimating the model given that we treat debt, taxes, and expenditures as observables.¹¹ We rewrite the federal government budget constraint in terms of debt-to-GDP ratio $b_t^m = (P_t^m B_t^m) / (P_t Y_t)$:

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

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

The (linearized) federal government expenditure as a fraction of GDP, \tilde{e}_t , is the sum of a

variable $\mu_t = \log(mu_t/mu)$ and we assume $\mu_t = \rho_\mu \mu_{t-1} + \sigma_\mu \varepsilon_{\mu,t}$.

¹¹An alternative approach consists of excluding one of the fiscal components, for example the series for debt. Our results are robust to this alternative specification. We also considered an alternative specification in which an observation error for the series of debt is included and the term premium shock eliminated. The results are virtually identical.

short term component \tilde{e}_t^S and a long term component \tilde{e}_t^L ($\tilde{e}_t = \tilde{e}_t^L + \tilde{e}_t^S$):¹²

$$\begin{aligned}\tilde{e}_t^L &= \rho_{e^L} \tilde{e}_{t-1}^L + \sigma_{e^L} \epsilon_{e^L,t}, \quad \epsilon_{e^L,t} \sim N(0, 1) \\ \tilde{e}_t^S &= \rho_{e^S} \tilde{e}_{t-1}^S + (1 - \rho_{e^S}) \phi_y(\hat{y}_t - \hat{y}_t^n) + \sigma_{e^S} \epsilon_{e^S,t}, \quad \epsilon_{e^S,t} \sim N(0, 1).\end{aligned}$$

The long term component is assumed to be completely exogenous and it is meant to capture the large programs that arise as the result of a political process that is not modeled here. Consistently with this interpretation, we assume that this component of government expenditure is known one year ahead. Instead, the short term component is meant to capture the response of government expenditure to the business cycle and responds to the (log-linearized) output gap ($\hat{y}_t - \hat{y}_t^n$), where \hat{y}_t^n is the natural output, the level of output that would prevail under flexible prices. Notice that government expenditure is the sum of *federal* transfers and good purchases.

The *federal* and *local/state* governments buy a fraction ζ_t of total output, equally divided among the J different goods. We define $g_t = 1/(1 - \zeta_t)$ and we assume that $\tilde{g}_t = \ln(g_t/g^*)$ follows the process:

$$\tilde{g}_t = \rho_g \tilde{g}_{t-1} + (1 - \rho_g) \phi_{e^S} \tilde{e}_{t-1}^S + \sigma_g \epsilon_{g,t}, \quad \epsilon_{g,t} \sim N(0, 1). \quad (15)$$

Before proceeding it is important to point out that we assume that local and state governments participate in purchasing goods and that they are supposed to run a balanced budget. Therefore, changes in net taxes at the state level are neutral as agents understand that they will be offset by future changes in the opposite direction. We believe this is a reasonable assumption as it is quite unlikely that in the United States local governments can exercise influence on the conduct of monetary policy.

Monetary and Fiscal Rules. The Central Bank moves the FFR according to the rule:

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\rho_R(\xi_t)} \left[\left(\frac{\Pi_t}{\Pi}\right)^{\psi_\pi(\xi_t)} \left(\frac{Y_t}{Y_t^n}\right)^{\psi_y(\xi_t)} \right]^{(1-\rho_R(\xi_t))} \sigma_R e^{\epsilon_{R,t}}, \quad \epsilon_{R,t} \sim N(0, 1) \quad (16)$$

where R is the steady-state (gross) nominal interest rate, Y_t^n is natural output, and Π is gross steady state inflation. The federal fiscal authority moves taxes according to the rule:

$$\tilde{\tau}_t = \rho_\tau(\xi_t) \tilde{\tau}_{t-1} + (1 - \rho_\tau(\xi_t)) \left[\delta_b(\xi_t) \tilde{b}_{t-1}^m + \delta_e \tilde{e}_t \right] + \delta_y (\hat{y}_{t-1} - \hat{y}_{t-1}^n) + \sigma_\tau \epsilon_{\tau,t}, \quad \epsilon_{\tau,t} \sim N(0, 1) \quad (17)$$

where $\tilde{\tau}_t$ denotes (linearized) tax revenues with respect to GDP.

¹²In what follows, for a given variable X_t , $\hat{x}_t \equiv \log((X_t/A_t)/(X/A))$ represents the percentage deviation of a detrended variable from its own steady state. For all the variables normalized with respect to GDP (debt, expenditure, and taxes) \tilde{x}_t denotes a linear deviation ($x_t = X_t - X$), while for all the other variables \tilde{x}_t denotes a percentage deviation ($\tilde{x}_t = \log(X_t/X)$). This distinction avoids having the percentage change of a percentage.

In equations (7) and (6), 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 H . The targets for inflation and debt are assumed to be constant over time.¹³ What changes is the strength with which the Government tries to pursue its goals, not the goals themselves. This is in line with the idea that policy makers might find high inflation or high debt acceptable under some circumstances, perhaps in order to preserve output stability, but not desirable in itself.

A.2 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:

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

2. Phillips curve:

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

3. Monetary policy rule:

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

4. Total Government purchases:

$$\tilde{g}_t = \rho_g \tilde{g}_{t-1} + (1 - \rho_g) \phi_{e^S} \tilde{e}_{t-1}^S + \sigma_g \epsilon_{g,t}$$

5. Fiscal rule:

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

¹³See Ireland (2007), Liu et al. (2011), and Schorfheide (2005) for models that allow for a time-varying target.

6. Debt:

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

7. Return long term bond:

$$\tilde{R}_{t,t+1}^m = R^{-1}\rho\tilde{P}_{t+1}^m - \tilde{P}_t^m$$

8. No arbitrage:

$$\tilde{R}_t = E_t \left[\tilde{R}_{t,t+1}^m \right]$$

9. Expenditure, short term component:

$$\tilde{e}_t^S = \rho_{e^S}\tilde{e}_{t-1}^S + (1 - \rho_{e^S})\phi_y(\hat{y}_t - \hat{y}_t^n) + \sigma_{e^S}\epsilon_{e^S,t}$$

10. Long term component (assumed to be known four periods in advance):

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

11. Term premium/maturity shock:

$$tp_t = \rho_{tp}tp_{t-1} + \sigma_{tp}\epsilon_{tp,t}$$

12. Technology:

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

13. Demand shock:

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

14. Mark-up shock:

$$\mu_t = \rho_\mu \mu_{t-1} + \sigma_\mu \epsilon_{\mu,t}$$

where $\mu_t = \log(mu_t/mu)$ is the percentage deviation of the markup, defined as $mu_t = \frac{1/v_t}{1/v_t - 1}$, from its own steady state.

A.3 Impulse responses

Here we report the impulse responses for the extended model under perfect information and learning.

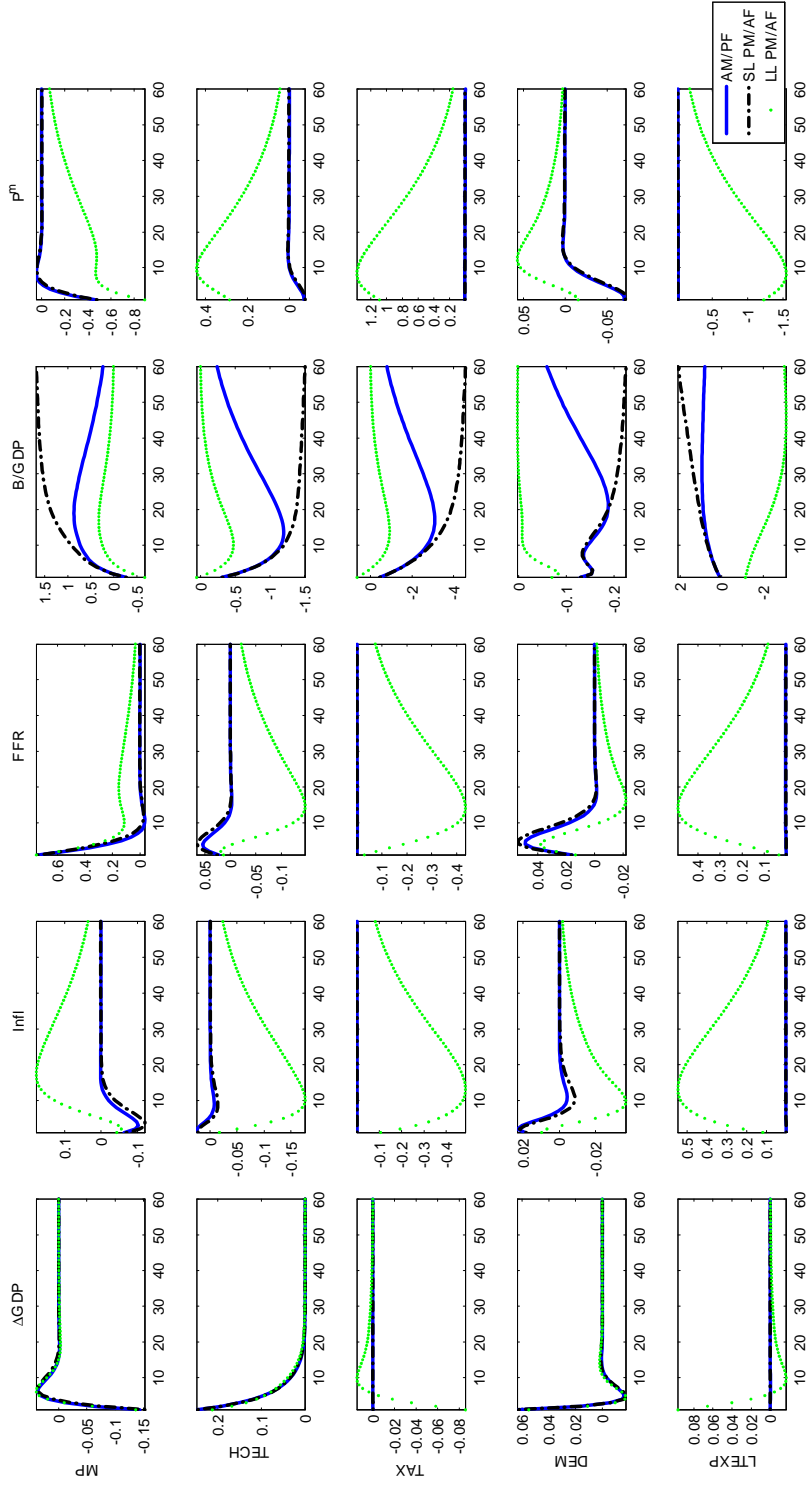


Figure 13: Impulse responses under perfect information.

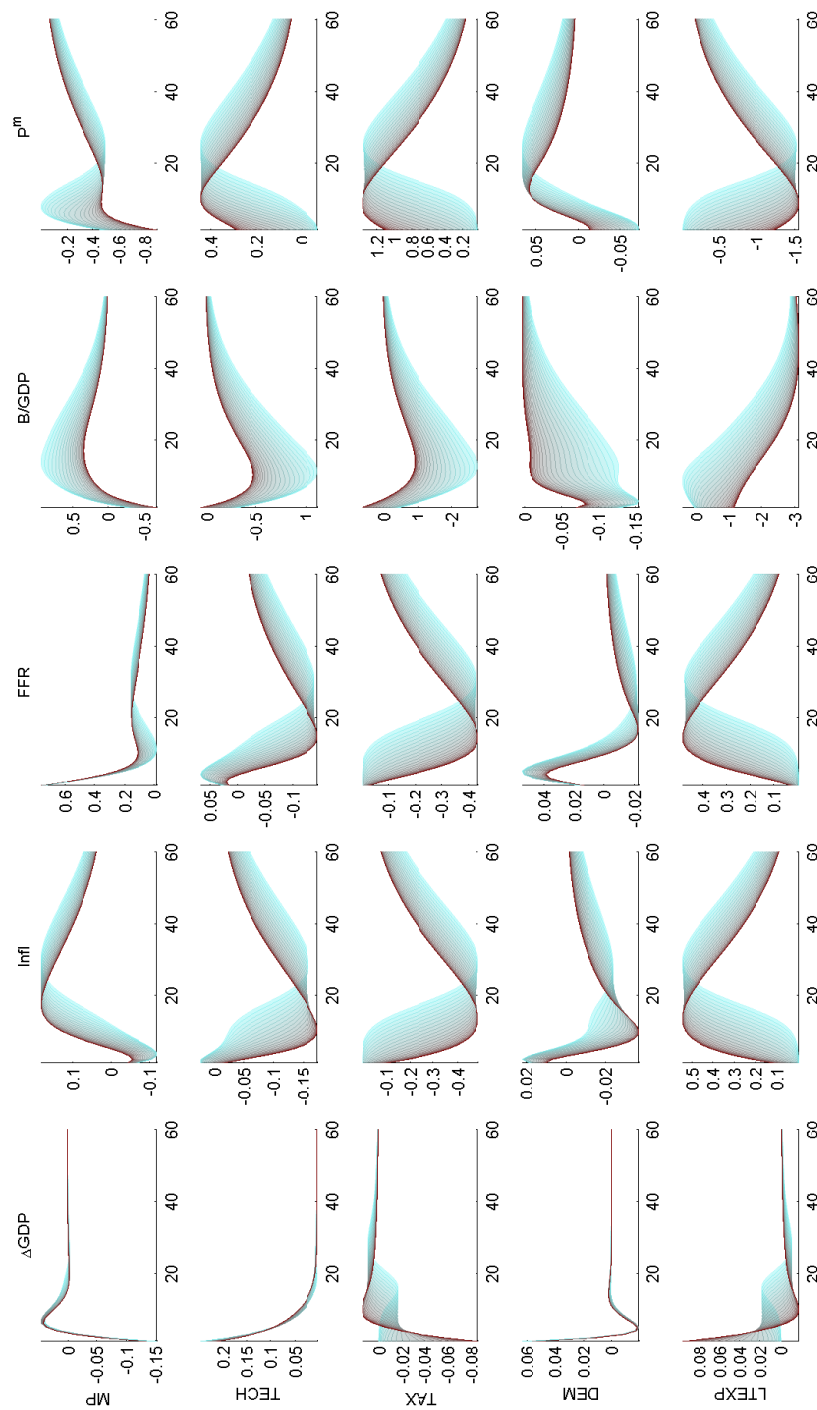


Figure 14: Impulse responses under learning assuming that the PM/AF regime prevails over the relevant horizon. Moving from the light-blue to the dark-red, the initial number of observed deviations increases. The impulse responses under the AM/PF are very similar, although not identical, to the ones that prevail under perfect information.

Parameter	Value	Parameter	Value	Parameter	Value
$\psi_\pi(\xi_t = 1)$	0.6244	δ_e	0.7045	$100\sigma_R$	0.1972
$\psi_\pi(\xi_t = 2)$	2.3522	δ_y	0.0869	$100\sigma_\tau$	0.4564
$\psi_y(\xi_t = 1)$	0.3716	ρ_e	0.9950	$100\sigma_a$	0.6518
$\psi_y(\xi_t = 2)$	0.1527	Φ	0.7779	$100\sigma_e$	0.3653
$\rho_R(\xi_t = 1)$	0.8480	ρ_a	0.4540	$100\sigma_d$	6.9498
$\rho_R(\xi_t = 2)$	0.8132	ρ_d	0.6125	$100\sigma_e$	0.3653
$\delta_{\tau,b}(\xi_t = 1)$	0	κ	0.0128	p_{11}	0.9000
$\delta_{\tau,b}(\xi_t = 2)$	0.0327	$100 \ln(\gamma)$	0.4896	p_{12}	0.0990
$\rho_\tau(\xi_t = 1)$	0.7306	b^*	0.9644	p_{22}	0.7000
$\rho_\tau(\xi_t = 2)$	0.8921	τ^*	0.1846	p_{33}	0.9900

Table 4: Parameter choices of the DSGE parameters and of the transition matrix diagonal elements based on Bianchi and Ilut (2011).