Monetary/Fiscal Policy Mix and Agents' Beliefs*

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Abstract

We estimate a model for the US economy that allows for a switch from a non-Ricardian to a Ricardian regime. Under the Ricardian regime the central bank has full control of inflation, while under the non-Ricardian regime inflation is allowed to move to stabilize debt. We find that the change occurred in the early '80s and we point out the following results. First, if the Ricardian regime had been in place since 1955 or if agents had anticipated the switch, the Great Inflation would not have occurred and debt would have been higher. This is because the rise in trend inflation and the decline in debt of the '70s are caused by a series of fiscal shocks that are inflationary only under the non-Ricardian regime. Second, the reversal in the debt-to-GDP ratio dynamics, the sudden drop in inflation, and the fall in output of the early '80s are explained by the regime switch itself. If the regime change had not occurred, inflation would have been high for another ten years. Third, the regime switch accounts for the change in the persistence and volatility of inflation.

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1 Introduction

Central bankers seem particularly aware of the potential risks linked to the lack of fiscal discipline. The Fed chairman himself claimed in a 2003 speech (Bernanke (2003)) that:

> *[...] The primary cause of the Great Inflation, most economists would agree, was over-expansionary monetary and fiscal policies, beginning in the mid-1960s and continuing, in fits and starts, well into the 1970s. The fiscal expansion of this period had a variety of elements, including heavy expenditures for the Vietnam War and President Johnson's Great Society initiatives. Monetary policy first accommodated the fiscal expansion, and then [...] began to power the inflationary surge on its own. [...]*

Nevertheless, when studying the evolution of inflation and output over the past fifty years, the role of fiscal policy has often been neglected. This despite the fact that in many of the general equilibrium models that are routinely used to analyze the effects of monetary policy, the central bank is able to control inflation only under the assumption that the fiscal authority is committed to adjusting primary surpluses in order to stabilize debt. As effectively shown by Leeper (1991), when this commitment is absent existence and uniqueness of a solution in a rational expectations general equilibrium model depend on the parameters characterizing the joint behavior of the monetary *and* fiscal authorities and policy interventions can have perverse and surprising effects. This has induced economists such as Cochrane (1998, 2001) and Sims (2009) to conjecture that the *original sin* that led to the rise of inflation in the '70s should be sought out in the conduct of fiscal policy during those years.

Figure 1 contextualizes the events highlighted by Bernanke, reporting the evolution of inflation and debt-to-GDP ratio over the period 1955-2009 together with the first reference to the Great Society initiatives ever made by President Johnson (May 1964) and the appointment of Paul Volcker (August 1979). Some stylized facts can be identified. First, trend inflation has been increasing steadily over the first half of the sample, while over the same period the debt-to-GDP ratio has been declining smoothly. During those years inflation was very persistent and volatile. Then, in the early '80s, a few quarters after the appointment of Volcker, inflation experienced a sudden and sharp drop that coincided with a deep recession. At the same time, the debt-to-GDP ratio started increasing steadily, until the early '90s. Since then inflation has been stable and its movements have been mostly at high frequencies (Stock and Watson (2007)).

In order to shed some light on the hypothesis that the events described above are the result of a dysfunctional interaction between monetary and fiscal policies, we estimate a micro-founded

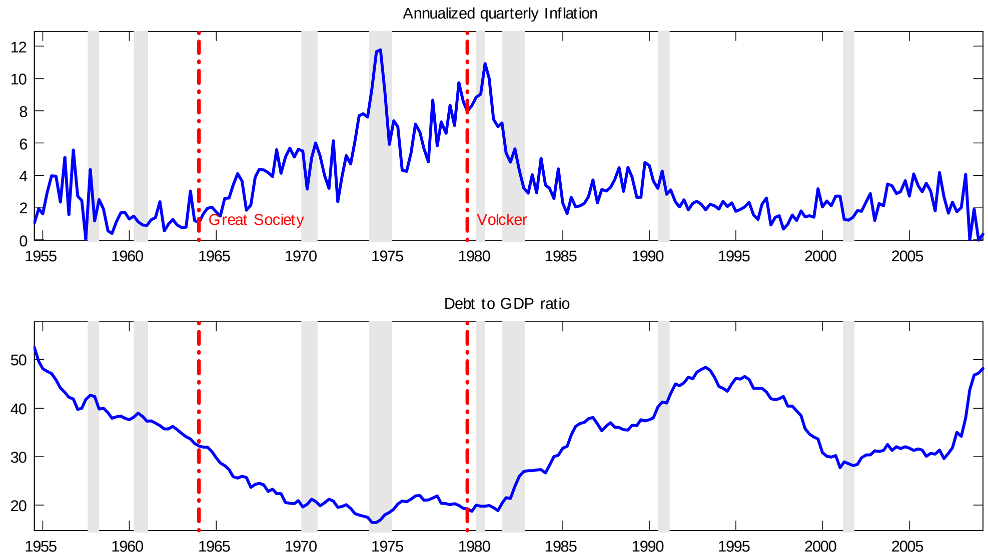

Figure 1: Annualized quarterly inflation and debt-to-GDP ratio over the sample 1954:III-2009:IV. The grey shaded areas represent the NBER recessions, while the two red vertical lines mark President Johnson's first ever public reference to the Great Society (May 1964) and the appointment of Paul Volcker (August 1979).

Dynamic Stochastic General Equilibrium (DSGE) model in which the monetary/fiscal policy mix is subject to a structural break from a non-Ricardian to a Ricardian fiscal regime (Woodford (1995)). Under the Ricardian regime, the fiscal authority is committed to keeping debt on a stable path and inflation is under the control of the central bank. Under the non-Ricardian regime this commitment is absent and the monetary authority allows inflation to move in a manner that keeps debt on a stable path. The two regimes then have very different implications for the way the shocks propagate through the economy. We find that the explanatory power of the model is maximized when the regime change occurs a few quarters after the appointment of Volcker and we show that the model dynamics and the timing of the regime change provide a unified theory for the stylized facts described above.

Using counterfactual simulations in which the shocks hitting the economy are left unchanged, we show that if the Ricardian regime had been in place from the beginning of the sample or if agents had been confident about the possibility of entering such a regime, the Great Inflation would not have occurred. This is because in our model the rise in trend inflation in the '70s is largely explained by the interaction between a series of fiscal shocks and the non-Ricardian regime that was in place at that time. Under such a regime the fiscal authority is not committed to increasing taxation to keep the debt-to-GDP ratio balanced. Therefore, a shock to government expenditure determines a long lasting increase in inflation. Given that the

Taylor principle does not hold, the central bank accommodates the increase in inflation, the real interest rate falls, and growth accelerates. At the same time, agents revise expectations about future short term interest rates upward causing a decline in the price of long term bonds. The increase in growth, the drop in the price of long term bonds, and the decline in the real interest rate determine a decline in the debt-to-GDP ratio. Therefore, the high inflation and the low debt of the '70s are the two sides of the same coin and are caused by the way fiscal shocks propagate through the economy when the non-Ricardian regime is in place. Consequently, in the moment the behavior of policymakers changes or agents are confident that it will change in the near future, the inflationary shocks of the '70s are sterilized, trend inflation does not rise, and the debt-to-GDP ratio turns out to be higher.

In the same way the non-Ricardian regime plays a key role in explaining the Great Inflation and the contemporaneous decline in the debt-to-GDP ratio, the switch to the Ricardian policy mix of the early '80s is the driving force behind the reversal of these dynamics and the large recession that occurred during those years. In order to make this point, we first consider two counterfactual simulations. In both of them, all of the shocks occurring *after* the regime change are set to zero. However, in the first simulation we also remove the change in the monetary/fiscal policy mix, whereas in the second one we keep it. In this latter case, the counterfactual series match the stylized facts described above, with inflation quickly dropping to its steady state level, the economy entering a recession, and debt increasing. On the other hand, when the regime change is removed, inflation, instead of falling, keeps rising for a couple of years and then slowly goes back to the steady state within approximately ten years. At the same time, the debt-to-GDP ratio remains low and the recession is substantially mitigated.

We then use actual and counterfactual impulse responses to inspect the forces that guide these results. When the non-Ricardian regime is in place, shocks to government expenditure cause a long lasting and slow moving increase in inflation, a decline in real interest rates, an increase in output, and consequently a decline in the debt-to-GDP ratio. We then show that the long term component of government expenditure experienced an acceleration around 1964, when President Johnson made the first ever public reference to the Great Society. The effects of these shocks slowly propagate for a long time and reach a peak several periods after the time of the impulse. However, the inflationary dynamics persist only as long as the non-Ricardian regime is in place. As soon as the switch to the Ricardian regime occurs, the effects of the shocks that occurred before the regime change suddenly disappear, causing a drastic change in the dynamics of the endogenous variables. The Taylor principle now holds, determining a sudden increase in the real interest rate. This causes a recession and a drop in inflation. At the same time agents revise their expectations for future short term interest rates downward with a consequent revaluation of government debt. These three effects, combined with a decline in tax revenues caused by the recession, determine an increase in the debt-to-GDP ratio. This increase persists for a while until taxes finally increase to repay debt.

The change from the non-Ricardian to the Ricardian regime also plays a key role in explaining the break in the volatility and persistence of inflation. Under the non-Ricardian regime inflation is substantially more volatile and persistent, as was the case over the first half of the sample, and fiscal shocks are very important, especially at low frequencies. Once the economy moves to the Ricardian regime the contribution of these shocks to the volatility of inflation is substantially reduced, given that their effects on the macroeconomy are offset, and inflation becomes less volatile and persistent. These changes occur while the stochastic process describing the exogenous disturbances remains unchanged, providing an important source of identification to separate the non-Ricardian from the Ricardian regime.

The study of the interaction between fiscal and monetary policy in determining inflation dynamics goes back to the seminal contribution of Sargent and Wallace (1981), that consider the problem in a deterministic environment, and proceeds with Leeper (1991), Sims (1994), and Woodford (1994, 1995, 2001) that focus on the problem of price determinacy.[1] Cochrane (1998, 2001) takes a model-free *frictionless view* of US inflation, in which a non-Ricardian regime is always in place and the real interest is exogenously determined. Therefore, movements in inflation are explained by revision in future expected real surpluses and the debt policy implemented by the fiscal authority. Our theoretical framework is more similar to Leeper (1991), given that we allow for a switch from a non-Ricardian to a Ricardian regime in a fully specified DSGE model, but we follow Cochrane (1998, 2001) in recognizing the importance of modeling a maturity structure of government debt. In Cochrane (1998, 2001) the fall of inflation of the early '80s can be rationalized by a revision in expected future surpluses induced by the Reagan tax reforms. Lower rates and a broader base mean better growth and eventually better tax revenues. In our case, the change in expectations is induced by a switch in the monetary/fiscal policy mix. Agents understand that once monetary policy stops accommodating the behavior of the fiscal authority, the government will have to move surpluses in order to stabilize debt. Section 4 shows that this mechanism works even when the change in the fiscal rule is partially delayed with respect to the change in monetary policy, given that what matters are agents' beliefs about the long run resolution of the conflict between the two authorities.

This paper is obviously related to the work of Clarida et al. (2000) and Lubik and Schorfheide (2004) that point out that the in the '70s the economy was subject to the possibility of self-fulfilling inflationary shocks because of the monetary policy rule that was followed at that time.

[1] See 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.

As in those papers, we find that monetary policy was passive in the '70s, but in our case the equilibrium is still determinate because of the fiscal rule that was in place at that time. Recently, Bhattarai et al. (2012) have revisited the results of Lubik and Schorfheide (2004) using a subsample analysis and allowing for the possibility that determinacy was guaranteed by the joint behavior of the monetary and fiscal authorities.

Primiceri (2006), Cogley and Sargent (2005), and Sargent et al. (2006) provide explanations for the rise and fall of inflation based on models in which the beliefs of the monetary authority around the structure of the economy are evolving over time. In these papers fiscal policy does not play any explicit role, while in our case the main ingredient is precisely a change in the monetary/fiscal policy mix. However, it is important to notice that the two approaches are not necessarily mutually exclusive. For example, Primiceri (2006) constructs a learning model in which the central bank is not aware that the underlying economy presents non-mean reverting inflation and initially finds the cost of a disinflation extremely high. In our model, both the high persistence of inflation and the perceived unfavorable sacrifice ratio result from the policy mix in place during those years.

To the extent that we provide a theory for movements in trend inflation, our work is also related to Cogley et al. (2008) and Coibion and Gorodichenko (2011). Cogley et al. (2008) study changes in the persistence of the inflation gap measured in terms of short- to medium-term predictability. In our paper, the decline in predictability between the pre- and post- Volcker eras is determined by the drastic change in the importance of fiscal shocks across the non-Ricardian and Ricardian regime. Coibion and Gorodichenko (2011) point out that the determinacy region in a model with positive trend inflation could be smaller than what is 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. Instead, in our model we find very persistent movements in inflation that resemble changes in trend inflation as a result of fiscal shocks under a non-Ricardian determinate equilibrium.

The idea that the monetary/fiscal policy mix can change over time has been explored by Davig and Leeper (2006) and Favero and Monacelli (2005). These authors estimate Markov-switching Taylor and fiscal rules, plugging them into a calibrated DSGE model. Instead, in this paper we estimate the policy rules and the other parameters of the model jointly. In this respect, the paper is closer to Bianchi (2012) that studies the evolution of the monetary/fiscal policy mix in the US assuming that agents have perfect information about the structure of the economy. In this paper, we relax this assumption and we point out that this is a key ingredient in obtaining the rise in the low frequency component of inflation during the '70s.

Finally, the paper is clearly related to the growing literature that allows for parameter instability in DSGE models. Justiniano and Primiceri (2008) allow for heteroskedasticity, while

Bianchi (2011), Davig and Doh (2008), and Fernández-Villaverde et al. (2010) also model changes in the parameters of the Taylor rule.

The content of this paper can be summarized as follows. Section 2 describes the model. Section 3 presents the main results. Section 4 considers two possible extensions. Section 5 points out that the current high level of debt is not necessarily inflationary. Section 6 concludes.

2 The Model

We make use of a new-Keynesian model similar to the one employed by Clarida et al. (2000) and Lubik and Schorfheide (2004), augmented with a fiscal block, external habits, inflation indexation, and a maturity structure for government debt.

Households. The representative household maximizes the following utility function:

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

subject to the budget constraint:

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

where D_t stands for real dividends paid by the firms, C_t is consumption, h_t is hours, W_t is the real wage, NT_t stands for net taxes, and C_s^A represents the average level of consumption in the economy. The parameter Φ captures the degree of external habit. The preference shock d_s has mean 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. Hall and Sargent (2010) show that these revaluation effects explain a significant fraction of the fluctuations of the debt-to-GDP ratio. Following Eusepi and Preston (2011) 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:

$$Y_t(j) = (P_t(j)/P_t)^{-1/\upsilon_t} Y_t \tag{2}$$

where the parameter $1/\upsilon_t$ is the elasticity of substitution between two differentiated goods. 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:

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

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

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

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

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:

$$\ln A_t = \gamma + \ln A_{t-1} + a_t \tag{4}$$

$$a_t = \rho_a a_{t-1} + \sigma_a \varepsilon_{a,t} \tag{5}$$

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

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

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, the term premium, and seigniorage. This shock is necessary to avoid stochastic singularity when estimating the model given that we treat debt, taxes, and expenditures as observables.[2] We rewrite the federal government budget constraint in terms of debt-to-GDP ratio b_t^m:

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

[2] An 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.

where all the variables are now expressed as a fraction of GDP and $R^m_{t-1,t} = (1 + \rho P^m_t) / P^m_{t-1}$ is the realized return of the maturity bond. We assume that $tp_t = \rho_{tp} tp_{t-1} + \sigma_{tp} \varepsilon_{tp,t}$.

The (linearized) federal government expenditure as a fraction of GDP $\widetilde{e}_t$ is the sum of a short term component $\widetilde{e}^S_t$ and a long term component $\widetilde{e}^L_t$ ($\widetilde{e}_t = \widetilde{e}^L_t + \widetilde{e}^S_t$):

$$\begin{aligned}
\widetilde{e}^L_t &= \rho_{e^L} \widetilde{e}^L_{t-1} + \sigma_{e^L} \epsilon_{e^L,t}, \ \epsilon_{e^L,t} \sim N(0,1) \\
\widetilde{e}^S_t &= \rho_{e^S} \widetilde{e}^S_{t-1} + (1 - \rho_{e^S}) \phi_y (\widehat{y}_t - \widehat{y}^n_t) + \sigma_{e^S} \epsilon_{e^S,t}, \ \epsilon_{e^S,t} \sim N(0,1).
\end{aligned}$$

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 $(\widehat{y}_t - \widehat{y}^n_t)$, where $\widehat{y}^n_t$ 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 $\widetilde{g}_t = \ln(g_t/g^*)$ follows the process:

$$\widetilde{g}_t = \rho_g \widetilde{g}_{t-1} + \left(1 - \rho_g\right) \phi_{e^S} \widetilde{e}^S_{t-1} + \sigma_g \epsilon_{g,t}, \ \epsilon_{g,t} \sim N(0,1). \quad (6)$$

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:

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\rho_R(\xi_t)} \left[\left(\frac{\Pi_t}{\Pi}\right)^{\psi_\pi(\xi_t)} \left(\frac{Y_t}{Y^n_t}\right)^{\psi_y(\xi_t)}\right]^{(1-\rho_R(\xi_t))} \sigma_R e^{\epsilon_{R,t}}, \ \epsilon_{R,t} \sim N(0,1) \quad (7)$$

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

$$\widetilde{\tau}_t = \rho_\tau(\xi_t) \widetilde{\tau}_{t-1} + (1 - \rho_\tau(\xi_t)) \left[\delta_b(\xi_t) \widetilde{b}^m_{t-1} + \delta_e \widetilde{e}_t\right] + \delta_y \left(\widehat{y}_{t-1} - \widehat{y}^n_{t-1}\right) + \sigma_\tau \epsilon_{\tau,t}, \ \epsilon_{\tau,t} \sim N(0,1) \quad (8)$$

where $\widetilde{\tau}_t$ is the level of tax revenues with respect to GDP in linear deviations from the steady

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

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

state.

In equations (7) and (8), ξ_t is an unobserved state variable capturing the monetary/fiscal policy combination that is in place at time t. The unobserved state takes on a finite number of values $j = 1, ..., m$ 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.[3] 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.

2.1 Determinacy Regions and Agents' Information Set

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

$$\Gamma_0 (\xi_t, \theta) S_t = \Gamma_1 (\xi_t, \theta^{sp}) S_{t-1} + \Psi (\xi_t, \theta^{sp}) Q\epsilon_t + \Pi\eta_t \tag{9}$$

with η_t a vector containing the expectations errors and Q is a diagonal matrix containing the standard deviations of the shocks.

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 to determine existence and uniqueness of a solution:

$$\widetilde{R}_t = \rho_R (\xi_t) \widetilde{R}_{t-1} + (1 - \rho_R) \psi_\pi (\xi_t) \widetilde{\pi}_t + ...$$

$$\widetilde{\tau}_t = \rho_\tau (\xi_t) \widetilde{\tau}_{t-1} + (1 - \rho_\tau (\xi_t)) \delta_b (\xi_t) \widetilde{b}^m_{t-1} + ...$$

There are two determinacy regions. The first one (Active Monetary/Passive Fiscal (AM/PF))

[3] See Ireland (2007), Liu et al. (2008), and Schorfheide (2005) for models that allow for a time-varying target.

is the most familiar one: The Taylor principle is satisfied and the fiscal authority moves taxes in order to keep the process for debt on a stable path. To grasp the intuition about this result, substitute the tax rule in the law of motion for government debt (assuming for simplicity that there is not autocorrelation in the tax rule) and isolate the resulting coefficient for lagged government debt:

$$\widetilde{b}_t^m = \left(\beta^{-1} - \delta_b\left(\xi_t\right)\right)\widetilde{b}_{t-1}^m + ...$$

Intuitively, in order to guarantee stability of government debt, we need this coefficient to be smaller than one ($\beta^{-1} - \delta_b\left(\xi_t\right) < 1$), in way that debt is mean reverting. This in turn requires the coefficient on debt in the tax rule to satisfy the condition $\delta_b\left(\xi_t\right) > \beta^{-1}$. Therefore, we can think of fiscal policy as passive to the extent that it *passively* accommodates the behavior of the monetary authority reacting strongly enough to debt fluctuations. 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 stabilize the process for debt. 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. Under this regime, even in absence of distortionary taxation, shocks to transfers 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.

Following Woodford (1995), we will sometimes refer to the AM/PF regime with the term Ricardian, while we will use the term non-Ricardian for the PM/AF regime. Notice that this straightforward one-to-one mapping between the current behavior of policy makers and the terminology introduced by Woodford is possible only when assuming that agents are not aware of regime changes, i.e. when solving the model with fixed coefficients. When agents are aware of regime changes 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.

In applied work, a lot of attention has been devoted to the AM/PF determinacy region and to the problem of indeterminacy (see Lubik and Schorfheide (2004)), whereas the PM/AF determinacy region has often been regarded as an implausible candidate to explain movements in the real economy. Instead, in this paper, we are interested in investigating the role that the lack of fiscal discipline has played in the evolution of the macroeconomy in the past 60 years. Therefore, our benchmark model allows for a one-time-only, fully credible regime change from the non-Ricardian to the Ricardian equilibrium. We assume that when agents observe a regime in place, they expect this regime to prevail forever. This assumption allows us to estimate the model using standard solution methods for rational expectations general equilibrium models (in our case, Sims (2002)'s solution method). Bianchi and Melosi (2011) show that this modeling assumption can be considered an approximation for a model with recurrent regime changes in which fully rational agents are uncertain about the persistence of the regime that they are in. Once agents have observed a regime for a prolonged period of time, they become so pessimistic about a regime change that the implied dynamics resemble the ones arising under fixed coefficients.

Alternatively, we could consider a model in which the economy never entered the non-Ricardian regime, but agents attach a positive probability to this event occurring because of the way monetary policy is conducted. If the probability is high enough, the effects of fiscal shocks would be very similar to the ones that characterize the non-Ricardian regime itself. We have also experimented with a model in which after the first switch agents become aware of both regimes and form expectations taking into account the possibility of regime changes. However, these and other alternative formulations add a substantial computational burden without delivering any additional insight with respect to what is presented here. Instead, what is crucial for our explanation of the rise and fall in inflation is the assumption that when under the non-Ricardian regime agents are not *confident* about the possibility of a switch to the Ricardian regime, given that this would make the model as a whole Ricardian. In other words, our results our robust to a model in which agents are aware but not optimistic about the possibility of a regime change. We illustrate this point in Section 4.

3 Results

Once the model is linearized and solved, it can be characterized as a regime switching VAR of the kind studied by Hamilton (1989), Chib (1996), and Sims and Zha (2006):

$$S_t = T(\xi_t, \theta^{sp}) S_{t-1} + R(\xi_t, \theta^{sp}) Q\epsilon_t, \;\; \epsilon_t \sim N(0, I) \tag{10}$$

$$H = \begin{bmatrix} p_{11} & 0 \\ p_{21} & 1 \end{bmatrix} \tag{11}$$

Given that we assume that agents are not aware of the possibility of regime changes the law of motion (10) depends exclusively on the parameters characterizing the regime that is in place at time t. The possibility of a structural break in the monetary/fiscal policy mix is modeled with a lower triangular transition matrix with the second regime being an absorbing state. Notice that this formulation allows for the possibility of a regime change, but it does not impose that such break occurred.

The law of motion (10)-(11) is then combined with a system of observation equations that includes seven observables: real GDP growth rate, annualized GDP deflator quarterly inflation, annualized quarterly FFR, annualized debt-to-GDP ratio on a quarterly basis, federal tax revenues to GDP ratio, federal expenditure to GDP ratio, and a transformation of government purchases to GDP ratio. Real GDP, the GDP deflator, and the series for fiscal variables are obtained from the Bureau of Economic Analysis (NIPA tables: BEA T1.1.6 L1, BEA T1.1.9 L1, total receipt T3.2, L37). The series for the FFR is obtained averaging monthly figures downloaded from the St. Louis Fed web-site, and the series for debt is downloaded from the Dallas Fed web-site. The sample spans from 1954:III up to 2009:IV.

We depart from other papers in the literature that reconstruct the series for government debt using the interest payments reported in the NIPA tables. Hall and Sargent (2010) argue that the interest payments reported by the Government are not consistent with any well defined law of motion for debt. Specifically, the Government reports data that do not fully take into account revaluation effects. Therefore, we implicitly reconstruct a series for interest payments that is consistent with the model, treating the series provided by the Dallas Fed as observable. Revaluation effects are in fact going to be very important in the context of our model that allows for a maturity structure of government debt.

The likelihood is computed using the modified Kalman filter described in Kim and Nelson (1999) and then combined with a prior distribution for the parameters to obtain the posterior. As a first step, a block algorithm is used to find the posterior mode, while a Metropolis algorithm is used to draw from the posterior distribution. Please refer to Appendix B for more details.

3.1 Parameters estimates and regime probabilities

Table 2 reports priors and posterior parameter estimates. The priors for the parameters that do not move across regimes are in line with previous contributions in the literature and are relatively loose. As for the parameters of the Taylor rule, the priors for the response to the output gap and the degree of autocorrelation are symmetric across regimes, whereas we have chosen asymmetric and truncated priors for the responses to inflation: Under the first regime, monetary policy is passive, whereas under the second regime, monetary policy is active. In a similar way, the priors for the response of taxes to government debt are asymmetric across the two regimes: Under the first regime, this parameter is restricted to zero, whereas under regime two it is expected to be fairly large. Overall, these priors imply that Regime 1 belongs to the PM/AF region, whereas Regime 2 corresponds to the AM/PF region. In order to separate the short and long term components of government expenditure we restrict the persistence of the long term component $\rho_{e^L} = .995$ and the standard deviation of its innovations $\sigma_{e^L} = .1$. Finally, we fix the annualized steady state level of inflation π^* to 2%, the discount factor β to

	Posterior				Prior		
	Mode	Mean	5%	95%		Mean	Std Dev
$\psi_\pi\,(\xi_t=1)$	0.6244	0.6115	0.4298	0.7873	G	0.80	0.30
$\psi_\pi\,(\xi_t=2)$	2.3522	2.3860	2.0117	2.8034	N	2.50	0.50
$\psi_y\,(\xi_t=1)$	0.3716	0.3844	0.2543	0.5369	G	0.25	0.15
$\psi_y\,(\xi_t=2)$	0.1527	0.1642	0.1042	0.2386	G	0.25	0.15
$\rho_R\,(\xi_t=1)$	0.8480	0.8506	0.8010	0.8939	B	0.50	0.20
$\rho_R\,(\xi_t=2)$	0.8132	0.8188	0.7756	0.8607	B	0.50	0.20
$\delta_b\,(\xi_t=1)$	0	–	–	–	F	–	–
$\delta_b\,(\xi_t=2)$	0.0327	0.0369	0.0214	0.0585	G	0.07	0.02
$\rho_\tau\,(\xi_t=1)$	0.7306	0.7292	0.6537	0.7985	B	0.50	0.20
$\rho_\tau\,(\xi_t=2)$	0.8921	0.8997	0.8358	0.9559	B	0.50	0.20
δ_e	0.7045	0.6962	0.6424	0.7412	N	0	0.25
δ_y	0.0869	0.0855	0.0547	0.1197	N	0.20	0.20
κ	0.0128	0.0122	0.0074	0.0183	G	0.40	0.15
Φ	0.7779	0.7868	0.6918	0.8592	B	0.50	0.20
ϕ_y	−0.3495	−0.3565	−0.4169	−0.3034	N	0.10	0.20
ρ_{e^S}	0.4700	0.4732	0.3858	0.5566	B	0.20	0.05
ϕ_{e^S}	0.2791	0.2620	−0.0780	0.5998	N	0.10	0.20
ρ_g	0.9743	0.9765	0.9569	0.9926	B	0.50	0.20
ρ_z	0.4540	0.4073	0.1602	0.6482	B	0.50	0.20
ρ_d	0.6125	0.5927	0.4571	0.7253	B	0.50	0.20
ρ_μ	0.0175	0.0267	0.0069	0.0577	B	0.50	0.20
ρ_{tp}	0.0750	0.0907	0.0295	0.1692	B	0.50	0.20
$100\ln(\gamma)$	0.4896	0.4919	0.4262	0.5578	N	0.52	0.05
b^*	0.9644	0.9552	0.8485	1.0598	N	1.00	0.10
g^*	1.2258	1.2245	1.2009	1.2473	N	1.10	0.10
τ^*	0.1846	0.1848	0.1827	0.1871	N	0.19	0.002
H_{11}^{sp}	0.9826	0.9744	0.9477	0.9929	Dir	0.90	0.06
H_{22}^{sp}	1	–	–	–	F	-	-
$100\sigma_R$	0.1972	0.1999	0.1836	0.2174	IG	0.50	0.50
$100\sigma_g$	0.3647	0.3679	0.3401	0.3980	IG	1.00	1.00
$100\sigma_z$	0.6518	0.7751	0.4766	1.1646	IG	1.00	1.00
$100\sigma_\tau$	0.4564	0.4626	0.4266	0.5019	IG	2.00	2.00
$100\sigma_d$	6.9498	7.4920	5.4687	10.0613	IG	1.00	1.00
$100\sigma_{e^S}$	0.3653	0.3694	0.3354	0.4065	IG	2.00	2.00
$100\sigma_{tp}$	3.7584	3.8060	3.4595	4.1948	IG	1.00	1.00
$100\sigma_\mu$	28.8049	32.2447	20.4817	48.2191	IG	1.00	1.00
$100\sigma_{e^L}$	0.1	–	–	–	F	–	–

Table 2: Modes, Means and 90% error bands of the DSGE parameters and of the transition matrix diagonal elements.

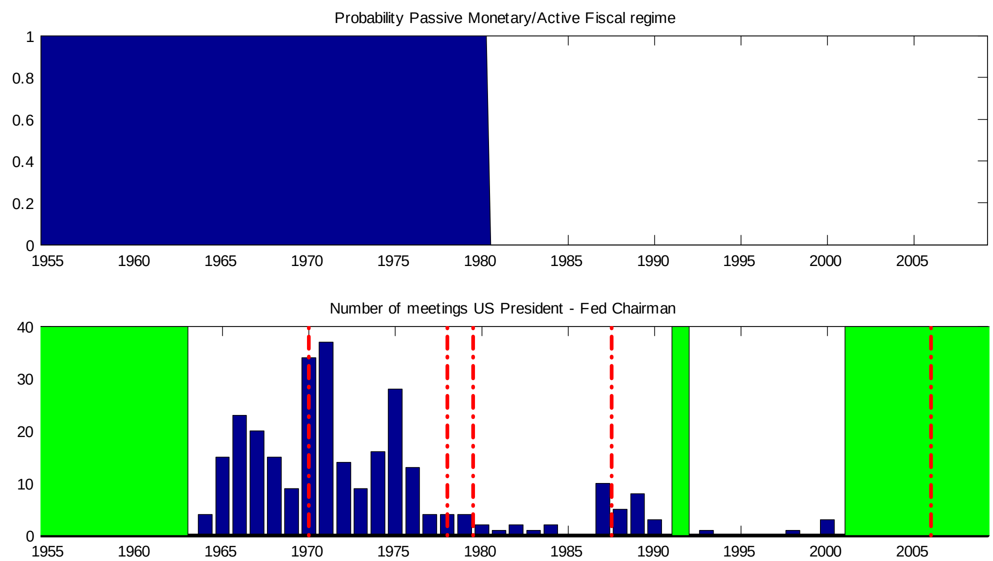

Figure 2: Top panel: Probability of the non-Ricardian regime (PM/AF) at the posterior mode. Lower panel: Meetings between presidents and Fed chairmen Including meetings at White House and phone calls. The green/light gray areas correspond to missing data.

.9985, and the average maturity to 5 years.

Regarding the parameters of the Taylor rule, under the AM/PF regime ($\xi_t = 2$) the Federal Funds rate reacts strongly to deviations of inflation from its target, while the output gap does not seem to be a major concern. The opposite occurs under the PM/AF regime. It is worth pointing out that the posterior estimates for the coefficient of the Taylor rule are relatively tight and the truncated priors are not binding. Under the PM/AF regime the response of taxes to debt is restricted to zero, while under the AM/PF regime it turns out to be significantly larger than the threshold value $1/\beta - 1 = .0015$.

As explained before, the timing of the regime change from the non-Ricardian to the Ricardian regime is left completely unrestricted. Figure 2 shows the (smoothed) probabilities assigned to the non-Ricardian regime. The estimates place the most likely time of the switch in mid-1980, a few quarters after the appointment of Volcker, and suggest a drastic change in the monetary/fiscal policy mix. Recall that under the non-Ricardian regime monetary policy accommodates the behavior of the fiscal authority, while under the Ricardian regime the central bank is free to pursue its goal of low and stable inflation. As a proxy for the degree of central bank independence, the lower panel of Figure 2 reports the number of meetings between the US president and the Fed chairmen over an year.[4] It is quite clear that such meetings were

[4]We are indebted to Fernando Martin for sharing these data with us (see Martin (2012)). The data are obtained from the Agenda of each president which is available at the respective presidential library. At this stage, the data for for 1991 and 1992 and after 2000 are not available.

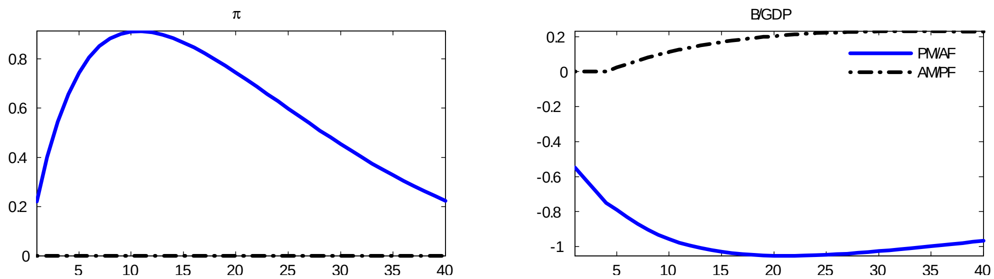

Figure 3: The figures show the responses of inflation and debt to a one standard deviation shock to the long term component of government expenditure under the non-Ricardian (solid blue line) and Ricardian (dashed black line) regimes.

substantially more frequent before the appointment of Volcker than afterwards. The average number of meetings per year was 15.56 over the period $1964-1979$, while it dropped to 2.05 over the period $1980-2001$.

While there is common agreement that Burns had often to succumb to the requests of the US administration and that Volcker was very committed to bring inflation down, the views on Martin are mixed, given the he was successful in keeping inflation low during the early years of the sample. However, the first spur of inflation occurred under his chairmanship, in the second half of the '60s. Meltzer (2009) provides ample evidence for the idea that Martin regarded himself as a *public servant* (see also Taylor (2011)). In Martin's own words, the central bank had to be "independent within the government", meaning that he did not "believe it is consistent to have an agent so independent that it can undertake, if it chooses, to defeat the financing of a large deficit, which is a policy of the Congress". Meltzer argues that this view of the role of the central bank led the Federal Reserve to accept "its role as a junior partner by agreeing to coordinate its actions with the administration's fiscal policy. Coordination permitted the chairman to discuss the administration's fiscal policy with the president, but he had little effect on decisions. In practice, coordination meant that the Federal Reserve would not raise interest rates much, if at all".

The non-Ricardian and Ricardian regime capture remarkably well these ideas. Figure 3 considers an increase in the long term component of government expenditure under the two alternative regimes. Under the Ricardian regime, given the assumption of non-distortionary taxation, the increase in expenditure does not have any effect on inflation, as agents understand that taxes will eventually rise. Instead, under the non-Ricardian regime agents anticipate that the increase in taxes will not be large enough and inflation starts rising. Given that the Taylor principle does not hold, the central bank reacts less than one-to-one to the increase in inflation, the real interest falls, and growth accelerates. The increase in inflation and output, combined with a decline in the price of long term bonds (caused by the revision of expected short term interest rates), determine a fall in the debt-to-GDP ratio. These dynamics will be key to understand the results shown in the next section and will be analyzed in detail in Section 3.3.

3.2 Counterfactual analysis

When working with models that allow for regime changes it is interesting to simulate what would have happened under alternative scenarios. The idea is to back-out the shocks from the estimates and then simulate an economy subject to the same shocks, but with interesting changes in the way policymakers behave. This kind of analysis is even more meaningful in the context of the MS-DSGE model employed in this paper. First of all, like a standard DSGE model, the MS-DSGE can be re-solved for alternative policy rules: The entire law of motion changes in a way that is consistent with the new assumptions around the behavior of the monetary policy authority. Furthermore, the solution depends on the agents' information set. This means that new counterfactual simulations can be explored: *Beliefs counterfactuals*. In these counterfactuals agents are endowed with specific beliefs about alternative regimes.

In this section we will make use of both *traditional* and *beliefs* counterfactual simulations to establish a series of results. First, if the Ricardian regime had been in place from the beginning of the sample, we would not have observed the rise in trend inflation, from which we conclude that the prevalence of the non-Ricardian regime during those years is important to understand the Great Inflation. Second, in the context of our model, the regime change, not a series of shocks, explains the dynamics of inflation, debt, and output during the early '80s. Third, if agents had been confident about moving to the Ricardian regime, the Great Inflation would not have occurred.

3.2.1 The Great Inflation

What caused the rise in trend inflation in the '70s? A series of adverse shocks, the behavior of policymakers, or a combination of the two? In order to answer this question we simulate an economy in which the sequence of non-policy shocks is kept unchanged, shocks to taxation and monetary policy are set to zero, and policymakers are assumed to behave according to the AM/PF regime over the entire sample.[5]

Figure 4 shows the output loss and the actual (dashed red line) and counterfactual series (solid blue line) for inflation, FFR, and debt-to-GDP ratio. It is apparent that under these assumptions the economy would have experienced a substantially lower level of inflation: While

[5]The results are similar when the shocks to monetary and fiscal policy are kept unchanged. We decide to remove them because these shocks are arguibly strictly related to the rules in place.

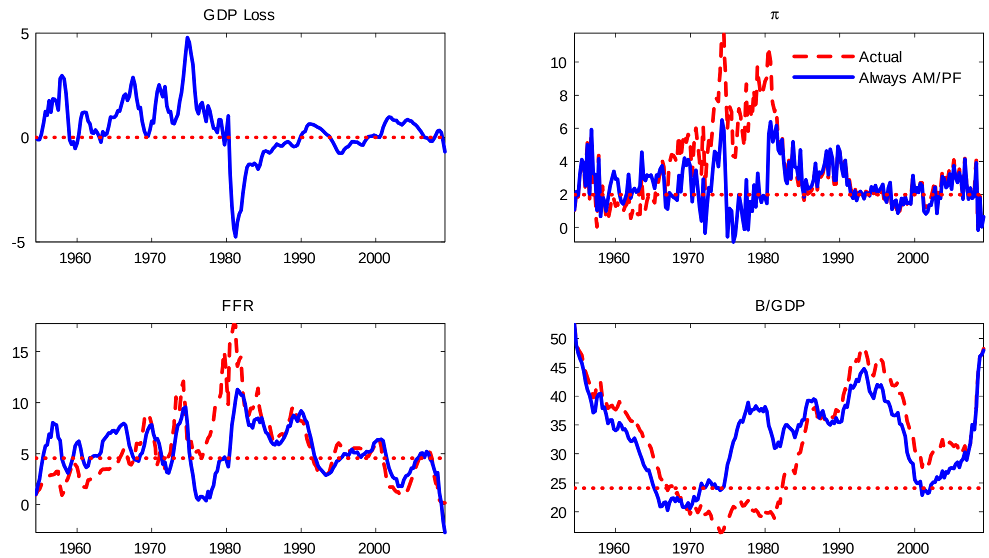

Figure 4: The Great Inflation: Counterfactual simulation in which all non-policy shocks are left unchanged and the Ricardian regime is assumed in place throughout the entire sample.

the high frequency movements associated with the oil crises of the '70s are substantially unaffected, the economy would not have experienced the rise in trend inflation. During the first half of the sample output losses would have been relatively large, with a peak of around 4.5% around the first oil crisis in 1974. However, the economy would have been able to avoid the painful recession associated with the Volcker disinflation, reabsorbing the losses experienced in the previous years. The debt-to-GDP ratio would have been slightly lower during the '60s, because of the larger response of taxes to debt, but it would have taken off in the '70s, despite fiscal policy being passive, for effect of the lower growth and higher real interest rates.

Summarizing, this counterfactual simulation suggests that the non-Ricardian regime plays a key role in the rise of trend inflation and the decline in the debt-to-GDP ratio observed during the '70s. As suggested in Figure 3 and further analyzed in Section 3.3, the joint behavior of inflation and debt in the '70s can be explained by the behavior of the economy in response to fiscal shocks under the non-Ricardian regime. When this regime is in place, expenditure shocks are inflationary and lead to a decline in the debt-to-GDP ratio, while when the Ricardian regime prevails, the shocks are sterilized, inflation is unaffected, and debt rises.

3.2.2 Revisiting the Volcker disinflation

In this second counterfactual we ask what would have happened if the regime change of the early '80s had not occurred. This simulation allows us to highlight how the switch from the PM/AF to the AM/PF regime can explain the events of the early '80s, namely the sudden

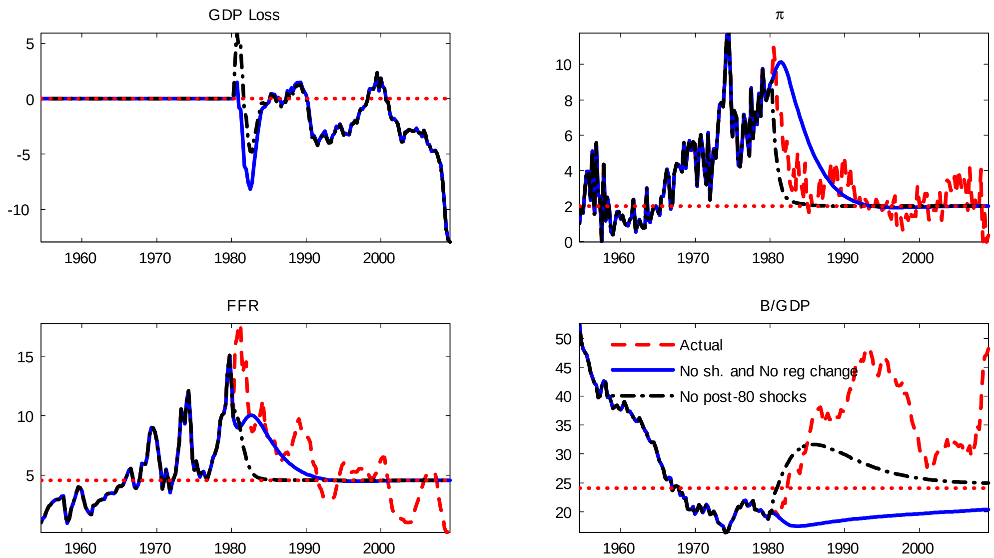

Figure 5: The Volcker Disinflation: Countefactaul simulation setting all the post regime shocks to zero. Two cases are considered. In the first case the regime change is kept (dashed-dotted black line), while in the second one the regime change is removed (solid blue line).

disinflation, the large recession, and the turnaround in the debt dynamics. In order to isolate the effects of the regime change, we set all the shocks following the second quarter of 1980 to zero and we construct two counterfactual simulations: The first keeping the regime change, the second removing it and assuming the non-Ricardian regime in place over the entire sample. Figure 5 compares the latter (solid blue line) with the former (dashed-dotted black line) and the actual series.

Three important facts stand out. First, without the regime change, inflation would have been above target for a *decade*. In fact, inflation would have kept rising for a couple of years, even if all the shocks have been set to zero. On the contrary, when the regime change is maintained inflation experiences a sudden drop, in line with what observed during those years. Second, if the regime change had not occurred, the economy would not have experienced the recession associated with the Volcker disinflation, as the *negative* output loss in the first panel shows. This is not the case when the regime change is maintained. Finally, when the regime change is kept, the model is able to match the turnaround in the path of the debt-to-GDP ratio that suddenly starts increasing, moves above the steady state, and then approaches it from *above*. On the contrary, when the regime change is removed, the variable shows an extremely smooth behavior and approaches the steady state from *below*.

Overall, these results show that the regime change and not the shocks accounts for three important stylized facts observed during the early '80s: The sudden drop in inflation, the large

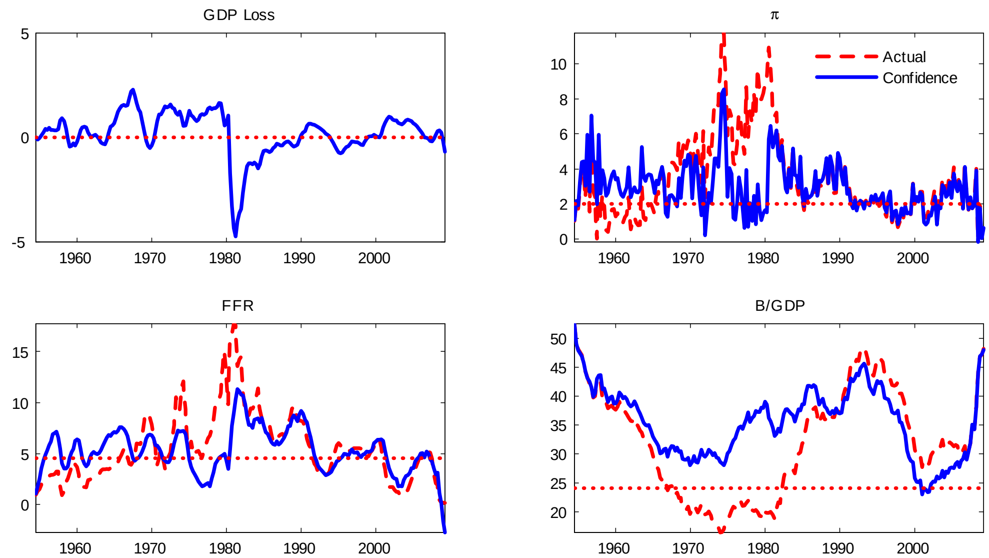

Figure 6: Confidence: Counterfactual simulation in which all non-policy shocks and regime sequences are left unchanged, but agents are confident that a switch to the Ricardian regime will eventually occur.

recession associated with the Volcker disinflation, and the sudden change in debt dynamics.

3.2.3 Confidence

This final subsection asks what would have happened if since 1955 agents had been *confident* about the possibility of moving to the AM/PF equilibrium. Specifically, when under the non-Ricardian regime, agents attach a 5% probability to moving to the AM/PF regime and staying there forever.[6] In other words, agents are confident that the economy will soon enter the AM/PF regime characterized by Ricardian fiscal policy, but they don't know when this is going to happen. In order to solve this model, we use the solution algorithm for MS-DSGE models proposed by Farmer et al. (2009). The solution algorithm takes into account that agents are aware of the possibility of regime changes. Therefore, the transition probabilities and characteristics of the different regimes have an impact on the law of motion in place today.

Figure 6 contains the output loss and the counterfactual and actual series for inflation, FFR, and debt-to-GDP ratio. During the '70s inflation would have been moving around the steady state without the persistent increase in trend inflation. In this respect, the results are similar to the ones obtained when imposing the Ricardian regime in place throughout the entire sample, but in this case they are exclusively driven by agents anticipating that in the *future* the monetary/fiscal policy mix will change. In other words, agents' beliefs can overturn the

[6]This value implies that the probability of being in the PM/AF regime in ten years is less than 13%.

effects of policymakers' actions. This point is also apparent when focusing on the behavior of output, which shows more contained fluctuations as a result of less aggressive monetary policy. Finally, the series for debt is now substantially larger with respect to the actual data and also with respect to the first counterfactual simulation. This should not be surprising, given that the tax rule in place still implies no response to the level of debt.

Summarizing, if in the '70s agents had been confident about the regime change that was going to occur a few years ahead, the persistent increase in the level of inflation would not have occurred and the losses in terms of output would have been more contained when compared to the case in which the AM/PF regime is imposed over the entire sample.

3.3 Impulse response analysis

In order to understand the forces driving the results illustrated by the counterfactual simulations, this section analyzes in detail how changes in policymakers' behavior or in agents' beliefs affect the propagation of the shocks through the economy. In the first subsection, we focus on the difference between the AM/PF and the PM/AF regime and on the role of agents' beliefs in the confidence counterfactual. In the second subsection, we consider the effects of a unexpected transition from the non-Ricardian to the Ricardian regime in order to shed light on the events of the early '80s.

3.3.1 Monetary/Fiscal Policy Mix and Agents' Beliefs

Figure 7 reports the responses of GDP, inflation, FFR, debt-to-GDP, and the real FFR to shocks to long term expenditure, FFR, and mark-up's. Three cases are considered. The first two correspond to the regimes recovered in the estimates: PM/AF (solid blue line) and AM/PF (dashed black line). The third one is based on the confidence counterfactual obtained assuming that the economy is under the PM/AF regime, but agents are confident that a regime change will eventually occur.

Government expenditure, Inflation, and Agents' Beliefs

The first column reports the responses to a shock to the long term component of government expenditure. The difference between the two regimes is particularly striking. Under the AM/PF regime, this shock does not have any effect on inflation and output, whereas under the PM/AF regime we observe a large and persistent increase in inflation, a drop in real interest rates, and an expansion in output. Under the AM/PF regime, the debt-to-GDP ratio starts increasing slowly and steadily when the announced increase in expenditure takes effect, while under the PM/AF regime we observe a sudden drop, due to higher expected future short term interest rates, higher inflation, and higher growth, and then a smooth decline mostly because of the negative real

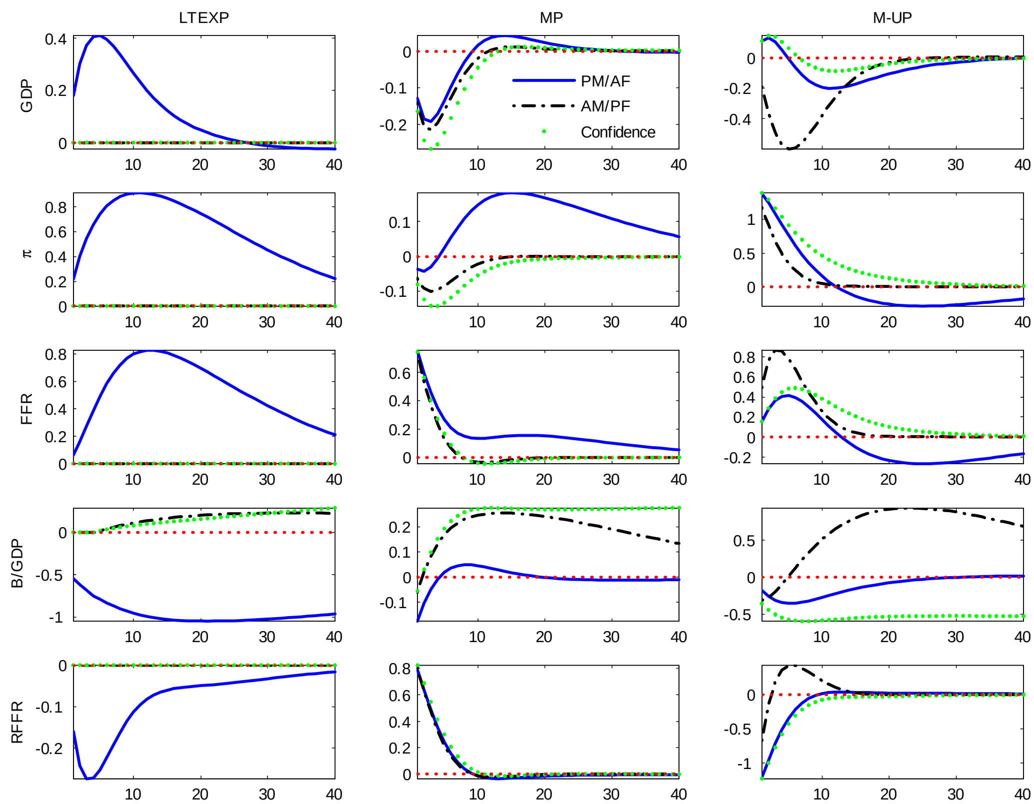

Figure 7: The three columns report the impulse responses to a long term component expenditure shock, a monetary policy shock, and a mark-up shock. Three cases are considered: PM/AF, AM/PF, and the confidence counterfactual in which the economy is under the PM/AF regime but agents are confident that it will soon enter the AM/PF regime.

interest rate. On the other hand, these effects disappear when agents anticipate the change in the policy mix: Under the confidence counterfactual the announced increase in government expenditure is not inflationary. Furthermore, debt behaves very similarly to the AM/PF case, even if there is no increase in taxation occurring over the relevant horizon, suggesting that an increase in debt is not necessarily inflationary.

The ability to control inflation

The second column reports the responses to a monetary policy shock. Under both the AM/PF and the PM/AF regimes, the Federal Reserve retains the ability to generate a recession and a subsequent short run decline in inflation. However, under the PM/AF regime, the initial decline in inflation fires back. This "stepping on a rake" effect (Sims (2009)) implies that the Central Bank might have the illusion of being able to control inflation, even if this ability is in fact lost in the moment that its actions are not adequately supported by the fiscal authority. The response of the debt-to-GDP ratio is also substantially different across the two regimes:

Under the AM/PF regime, the ratio increases quickly due to the decline in output and high real interest rates, whereas under the PM/AF regime we observe a sudden drop caused by a value loss, then a modest increase due to the slowdown of the economy, and finally a smooth decline as a consequence of the high inflation. However, the "stepping on a rake" effect is neutralized and monetary policy authority regains the ability to control inflation if agents are confident about the possibility of moving to the Ricardian equilibrium. In fact, under the confidence counterfactual impulse response, inflation declines smoothly and the debt-to-GDP ratio increases without showing any revaluation effect. This occurs despite the fact that the tax 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. What matters is that agents remain confident about the long run commitment to increase taxes in order to repay debt.

The "stepping on a rake" effect represents a key ingredient in linking our results to the work of Primiceri (2006), Cogley and Sargent (2005), and Sargent et al. (2006). In these papers the rise and fall of inflation result from the evolution of the central banks' beliefs about the structure of the economy. A central insight of these papers is that the Federal Reserve might have been reluctant in bringing inflation down in the '70s because of the perceived trade-off between inflation and output growth. Our results suggest that this trade-off was in fact there and was due to a lack of coordination between the monetary and fiscal authorities. In the moment the central bank tries to take the initiative and reduce inflation without coordinating with the fiscal authority, the result is a recession and a further increase in inflation.

Mark-up shocks

The switch to the Ricardian regime does not imply that all shocks affecting inflation can be neutralized. The third column displays the responses to a mark-up shock. In the short run inflation increases independent of the regime in place. However the response of the FFR and the implied responses of the real interest rate and output are still very different across regimes. Specifically, the reaction of the Fed causes a deep recession under the AM/PF regime, while under the PM/AF regime output is much less volatile and in the short run we observe a boom, instead of a decline. The debt-to-GDP ratio increases substantially under the AM/PF regime, while under the PM/AF regime the initial decline is rebalanced by low inflation in the medium and long run. The dynamics under the confidence counterfactual, are now very similar to the ones implied by the PM/AF regime. The only notable difference is represented by the large initial drop in the value of long-term bonds under the confidence counterfactual reflecting the expectation of larger short term interest rates as a result of the anticipated regime change.

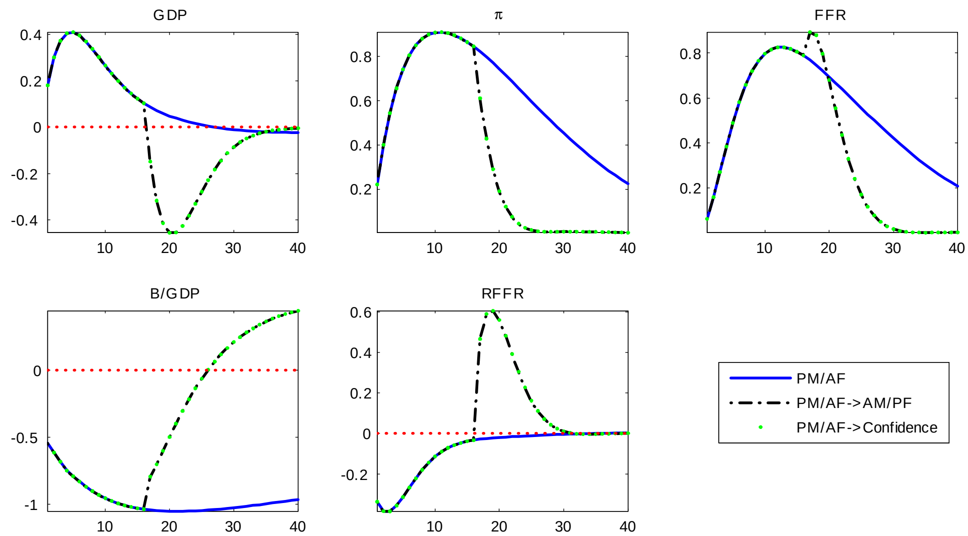

Figure 8: Impulse responses to a one standard deviation increase in the long term component of government expenditure. The solid blue line represents the case in which the economy is constantly under the PM/AF regime, the black dashed line assumes that after four years an unexpected switch to the AM/PF regime occurs, while the green dotted line assumes that in every period there is a 5% probability that the switch will occur.

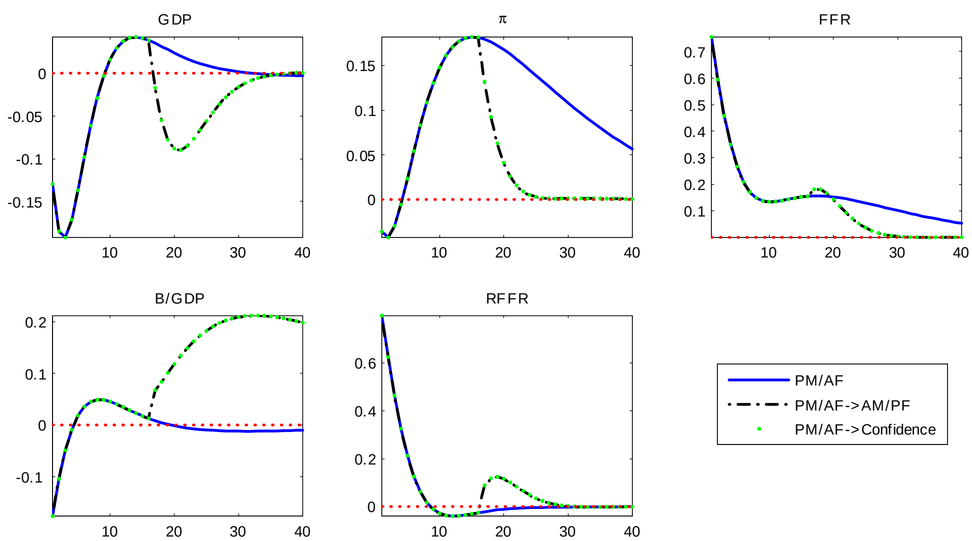

Figure 9: Impulse responses to a one standard deviation shock to the FFR. The solid blue line represents the case in which the economy is constantly under the PM/AF regime, the black dashed line assumes that after four years an unexpected switch to the AM/PF regime occurs, while the green dotted line assumes that that after four years it is announced that in every period there is a 5% probability that the switch will occur.

3.3.2 From PM/AF to AM/PF: A sudden disinflation

Figure 8 reports the responses of GDP, inflation, debt-to-GDP ratio, and the real FFR, to a one standard deviation increase in the long term component of government expenditure. The solid blue line represents the case in which the economy is constantly under the PM/AF regime. The black dashed line assumes that after four years an unexpected fully credible switch to the AM/PF regime takes place. Finally, under the dotted green line after four years it is announced that in every period there will be a 5% probability of entering the absorbing Ricardian regime. This last case corresponds to the confidence counterfactual.

The benchmark case that assumes no change in the policy mix has been discussed before. Now consider the effects of a sudden change to the AM/PF. First, inflation suddenly drops, moving back to the steady state in less than a couple of years. At the same time, the associated sharp increase in the real interest rate causes a recession. The low debt level and the recession imply that even if fiscal policy is now passive, taxes do not immediately increase. Finally, agents revise downward their expectations about future short term interest rates. These events contribute to determine a swing in the dynamics of the debt-to-GDP ratio that starts growing at a sustained pace. All of these four features, 1) a sudden and fast drop in inflation, 2) a large recession, 3) large and positive real interest rates, and 4) a steady increase in the debt-to-GDP ratio, have all characterized the early '80s, following the Volcker appointment. Our model captures all of them through a sudden change in the monetary/fiscal policy mix that radically modifies the impact of the shocks that occurred in the '70s. Suddenly, a series of shocks that were inflationary under the non-Ricardian equilibrium are neutralized under the Ricardian regime. In the moment the economy moves to the Ricardian regime, the *residual* inflationary effects of these shocks disappear because agents learn that from that moment on, the government will move taxes in order to repay debt.

At the same time, the change in the policy mix determines a switch in the effectiveness of monetary policy, as Figure 9 illustrates. As explained before, under the PM/AF equilibrium the monetary policy shock determines only an initial decline in inflation, followed by a substantial increase due to the lack of commitment to keeping debt on a stable path through taxation. However, when the regime change occurs this inflationary effect suddenly disappears and we observe a drop in inflation. At the same time the economy enters a recession as a consequence of the increase in the real interest rate.

3.4 Discussion

The impulse responses shown above help in understanding the counterfactual simulations. First, they illustrate that the rise in trend inflation can be explained by a lack of fiscal discipline that

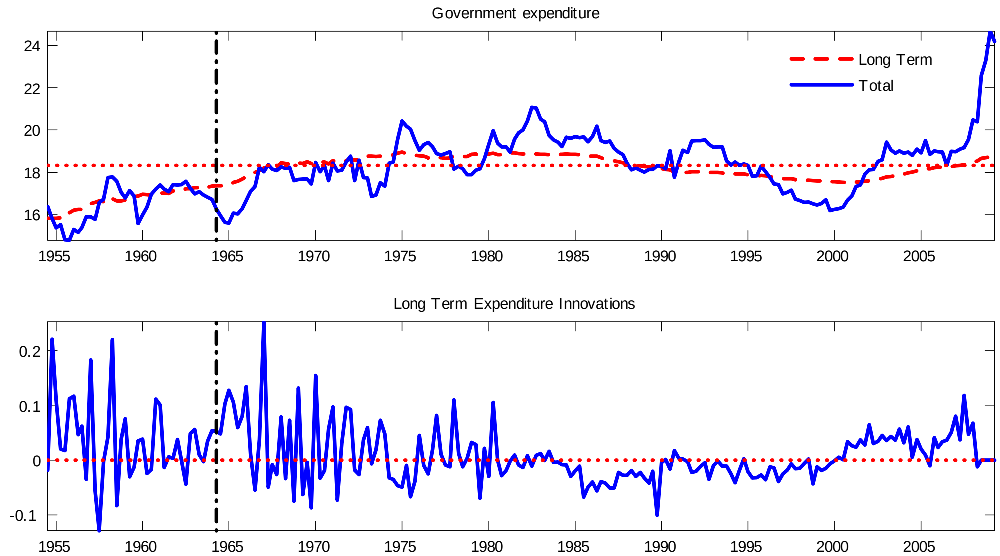

Figure 10: The top panel contains total governement expenditure as a fraction of GDP and its filtered long term component. The horizontal line represents the steady state value. The lower panel reports the innovations to the long term component. The vertical bar marks the President Johnson's first ever public reference to the 'Great Society' (May 7, 1964).

made a series of fiscal shocks inflationary and undermined the ability of the monetary authority to control inflation. In fact, the joint behavior of inflation and debt in response to a long term expenditure shock under the PM/AF regime is in line what observed over the first half of the sample, with a persistent increase in inflation and a slow-moving decline in the debt-to-GDP ratio. Second, they illustrate why the increase in trend inflation practically disappears when the Ricardian regime is imposed over the entire sample or agents are confident about the possibility of moving to such a regime: In both cases, the fiscal shocks that under the PM/AF regime are inflationary are completely sterilized and the Federal Reserve regains its ability to control inflation. In the first case, this occurs because the policy mix is reversed, while in the confidence counterfactual the result is exclusively driven by the expectation mechanism: Agents are confident that at some point in the future the policy mix will change and this is enough to neutralize the effects of the current policymakers' behavior. Finally, not all shocks that affect inflation can be completely sterilized. For example, in the short run the impact of a mark-up shock on inflation is substantially unaffected by the regime change. This explains why the counterfactual simulations determine a drastic change in the behavior of inflation at low frequencies, while they have little impact on its movements at medium and high frequencies.

Bianchi (2011) and Fernández-Villaverde et al. (2010) have conducted counterfactual simulations in micro-founded model focusing on the consequences of changes in monetary policy only, assuming that a passive fiscal policy is always in place. A common finding is that replacing Burns with Volcker would have implied only a minor reduction of inflation in the '70s. In a similar way, removing the appointment of Volcker in August '79 would have only slightly delayed the return of inflation to the steady state. This is because different monetary policy regimes only affect how the burden of adverse shocks is redistributed between output and inflation. Instead, when a change in the entire policy mix is considered a series of fiscal shocks that are inflationary under the PM/AF regime are completely sterilized under the AM/PF regime. Furthermore, changes in the monetary/fiscal policy mix are able to determine significant changes in the persistence of inflation, as documented in Section 3.5. Therefore, the switch to the Ricardian regime becomes crucial to determine a fast return of inflation to the steady state.

Given the important role played by fiscal shocks, it is important to document that the model does not imply an unrealistic behavior for the long term component of government expenditure. The top panel of Figure 10 reports the model implied long term component of expenditure,[7] showing that in fact the variable increases steadily in the '70s, but also that its behavior is remarkably smooth and arguably similar to what would be obtained by pre-filtering the data. The second panel reports the long term component innovations. It is worth emphasizing that the most notable acceleration in the long term component occurs around the President Johnson's first ever public reference to the 'Great Society' that took place during a speech on May 7, 1964 at Ohio State University (marked by the vertical bar).

Therefore, the model provides support for the argument proposed by Bernanke (2003) that the early manifestation of the Great Inflation can be tracked back to the Great Society initiatives. At the same time, it is important to keep in mind that these shocks are inflationary only under the non-Ricardian regime. If the Ricardian regime had been in place, the increase in inflation would not have occurred. This suggests that the political will of raising taxes in order to finance the increased level of expenditure was playing a key role. Given the nature of these programs, the American public might not have found it fully credible that future administrations would have taken the necessary steps to cover the higher level of expenditure.

Finally, the timing of the switch from the non-Ricardian to the Ricardian regime is consistent with the view of Goodfriend and King (2005) that "the start of a deliberate disinflation dates to late 1980" and that the initial increase in the FFR following Volcker's appointment did not represent a substantial departure from the way monetary policy was conducted in the '70s: A timid attempt at controlling inflation, resulting in even higher inflation. The results reported in Figure 9 provide an explanation for why this first attempt was not successful. If the central bank increases the policy interest rate without the support of the fiscal authority the result is

[7] The series is obtained filtering the data at the posterior mode.

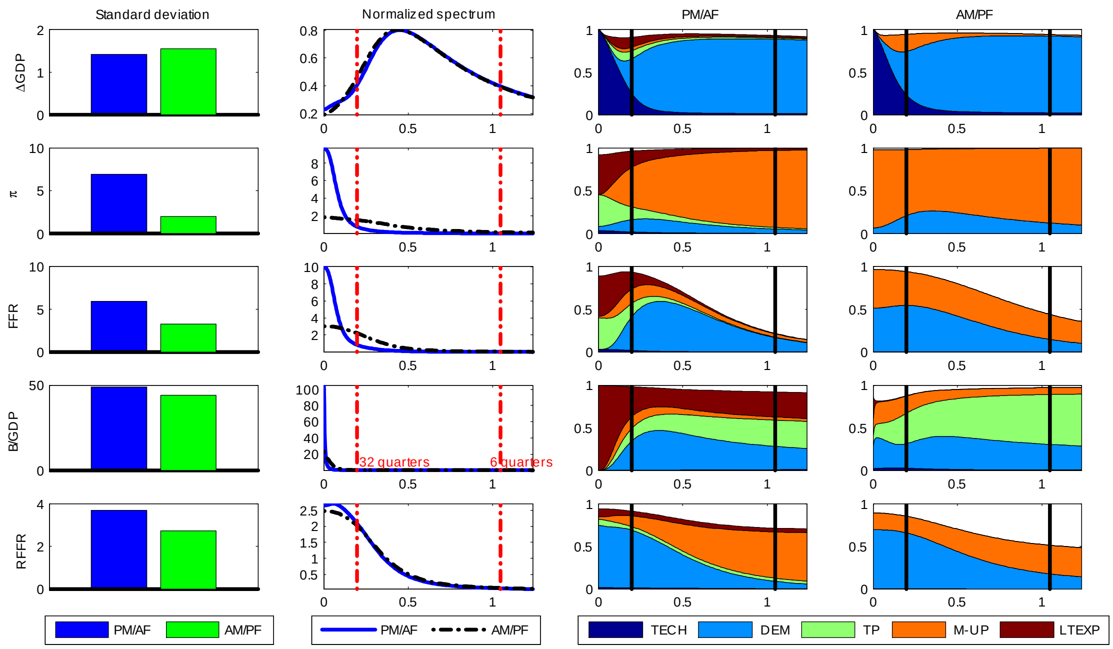

Figure 11: The figure contains the model implied standard deviations under the two regimes (first column), the normalized spectrum for the two regimes (second column), and the variance decomposition in the frequency domain under the PM/AF regime (third column) and the AM/PF regime (fourth column). All results are computed at the posterior mode and the vertical bars mark the business cycle frequencies (between 6 and 32 quarters).

even higher inflation. However, in the moment the monetary/fiscal policy changes, monetary policy becomes effective and inflation drops. Meltzer (2009) explains how Paul Volcker started working on the task of bringing inflation down immediately after his appointment in August 1979. However, this first attempt suffered an important delay when the Fed *accommodated* the request of the Carter administration to introduce credit controls on March 14, 1980. This choice proved to be disastrous for two reasons. First, it determined a decline in the FFR and did not prevent inflation from rising. Second, it undermined once again the independence of the monetary authority. The result was that the Federal Reserve had to start the effort all over again. The credit controls were removed in July 1980 and this time Volcker kept interest rates high for a prolonged period of time with no interference by the Reagan administration. This perseverance in face of an hostile public opinion and the implicit support of the fiscal authority can be regarded as the signal that the monetary/fiscal policy mix had finally changed.

3.5 Variance decomposition

Figure 11 contains results for the variance decomposition at the posterior mode. The four columns contain, respectively, the standard deviations, the normalized spectrum, and the variance decompositions in the frequency domain under the two regimes. The vertical bars mark the business cycle frequencies (between 6 and 32 quarters). The normalized spectrum is computed by dividing the spectrum by the overall variance.

Regarding the volatility of inflation, we observe a substantial reduction moving from the PM/AF to the AM/PF regime. Furthermore, this decline in volatility is largely determined by a fall in the persistence of inflation, as the standardized spectrum shows. Therefore, the change from the non-Ricardian to the Ricardian regime delivers the change in the stochastic properties of inflation that has been noticed elsewhere in the literature (Stock and Watson (2007) and Cogley et al. (2008) among others) and that is sometimes associated with a stabilization of the target for inflation. When looking at the contribution of the different shocks in determining the volatility of inflation, we find that up to 50% of the low frequency variability is explained by shocks to the long term component of government expenditure, while the business cycle frequencies are especially affected by mark-up shocks. The term premium shock also plays an important role in explaining the low frequency movements in inflation, suggesting that movements in the cost of financing or the maturity structure can have an impact on inflation dynamics if a Ricardian regime is not in place. This is an interesting point, especially in light of the recent downgrade of US debt. However, we are not explicitly modeling these aspects of the model, so this result should be taken with caution. Quite importantly, none of these two shocks play any role once the economy moves to the AM/PF regime. In this case, demand and mark-up shocks explain inflation volatility almost entirely, with the latter getting the lion's share. Summarizing, movements in trend inflation can be explained by fiscal shocks when there is a lack of commitment to stabilize debt. When this commitment is present, inflation volatility is mostly at business cycle frequencies.

Not surprisingly, the variance decomposition of the FFR shares similar features. The volatility and the persistence are greatly reduced when moving to the AM/PF regime and long term expenditure shocks are important for the low frequency movements only when the PM/AF regime is in place. Monetary policy shocks (not reported here) explain a large fraction of the remaining volatility at business cycle and high frequencies.

The change in the volatility of the debt-to-GDP ratio is less pronounced. However, the variance decomposition shows some interesting features. First, under the PM/AF regime long term expenditure shocks affect both low and high frequency movements, with the high frequency contribution reflecting the revaluation effects that follow a long term expenditure shock. Second, the contribution of the long term expenditure shock becomes much less important once the

AM/PF regime is in place. This suggests that the importance of this shock derives mostly from the non-Ricardian effects that arise under the PM/AF regime and not from its direct impact on the law of motion of debt.

Finally, the volatility of output growth is slightly larger under the AM/PF regime. A large fraction of the GDP growth volatility is at business cycle frequencies and we do not observe a significant shift following the regime change. Technology shocks affect the persistence of output growth, while preference shocks have a large impact at business cycle frequencies. Even for output, long term expenditure shocks are important only under the PM/AF regime. The contribution is mostly at business cycle frequencies, suggesting that the lack of fiscal discipline can affect the volatility of the business cycle.

4 Extensions

In this section we consider two extensions meant to highlight that the results shown above are robust to two important changes regarding agents' beliefs and the timing of the change in the conduct of fiscal policy. Specifically, we first relax the assumption that agents in the '70s were not aware of the possibility of entering the Ricardian regime. Then, we show that as long as agents interpret the appointment of Volcker as a signal of a future switch in the conduct of fiscal policy mix, it is not necessary that the two changes are synchronized.

Figure 12 reports a counterfactual simulation obtained relaxing the assumption that in the '70s agents were not aware of the possibility of exiting the PM/AF regime. We assume instead that while under such a regime agents face uncertainty about which regime will eventually prevail. Specifically, in every period they attach 4% probability to the resolution of uncertainty. Conditional on this happening, entering the Ricardian regime is regarded as likely as remaining in the PM/AF regime forever. From the figure it is clear that even if the Ricardian regime was given a fair chance to occur, it is enough that agents consider the alternative scenario as equally likely to prevent significant changes in the macroeconomy. In other words, in order to eliminate the effects associated with the PM/AF regime is not enough to make agents *aware* of the alternative scenario.

In Figure 13 we consider the possibility that the changes in monetary and fiscal policies were not synchronized. Specifically, the change in fiscal policy is assumed to take place ten years after the switch in monetary policy. Agents understand that a situation in which both regimes are active is not sustainable, given that it implies explosive dynamics for debt. Therefore, eventually fiscal policy will have to adjust in order to accommodate the renovated commitment to low and stable inflation implied by the appointment of Volcker. This assumption is modeled assuming that in every period agents attach a 2% probability to exiting this transitory period.

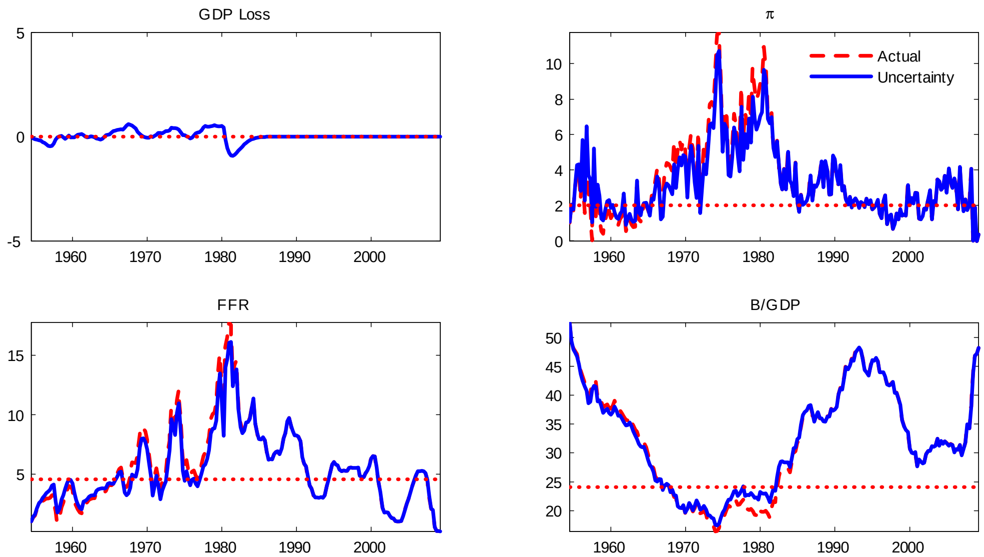

Figure 12: Uncertainty: Counterfactual simulation obtained assuming that before the change of the early '80s agents were attaching equal probabilities to entering an absorbing Ricardian regime or entering an absorbing non-Ricardian regime.

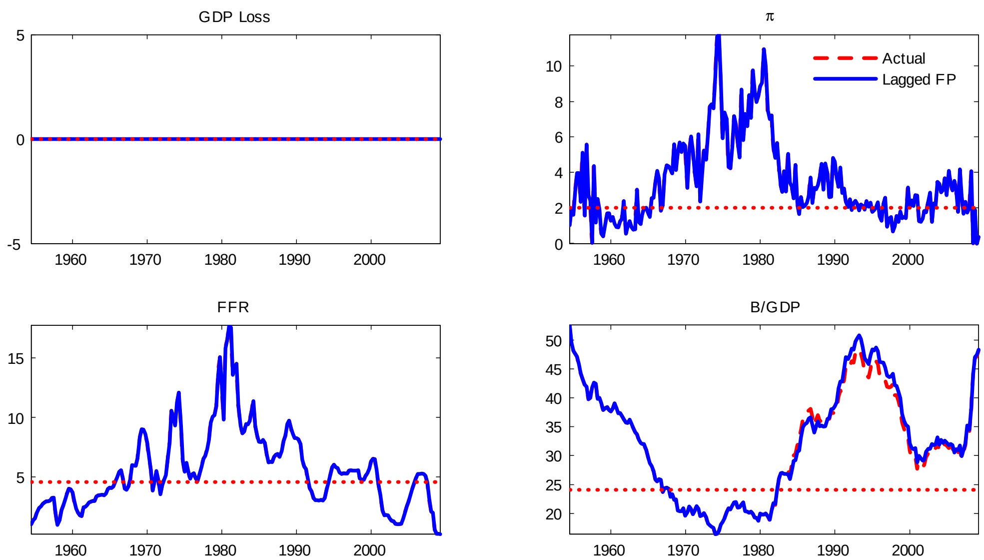

Figure 13: Lagged fiscal policy change: Counterfactual simulation obtained assuming that change in fiscal policy occurred ten years later the change in monetary policy. Agents are assumed to foresee such regime change.

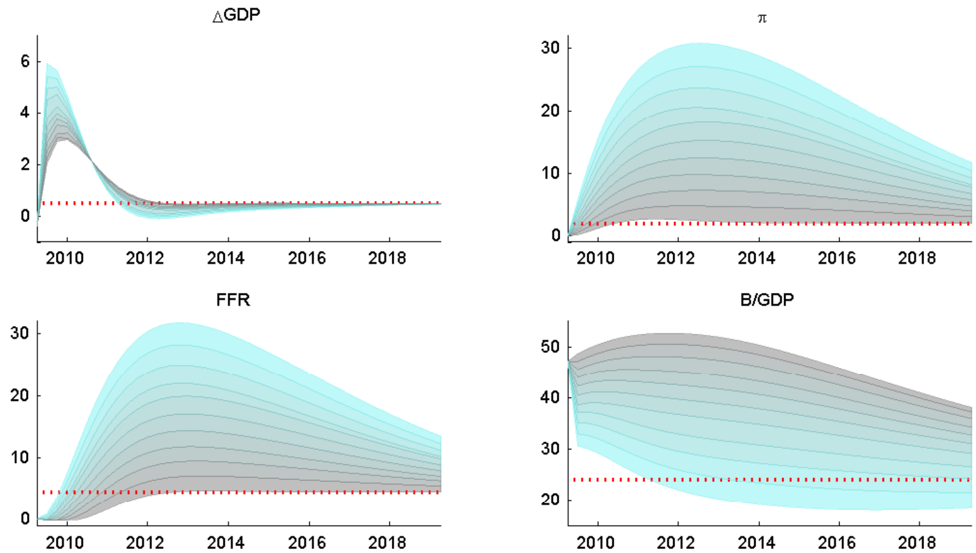

Figure 14: The figure reports expectations for GDP growth, inflation, FFR, and debt-to-GDP ratio conditional on different agents' beliefs regarding the evolution of the monetary/fiscal policy mix. In each case the economy is currently in the AM/PF regime. The darkest line assumes that agents are confident that the economy will stay in the AM/PF regime and as the lines become lighter and lighter the probability of moving to the PM/AF regime increases.

Not surprisingly, the path for debt is slightly different as the rule in place over the period 1980-1990 has changed, but this does not affect the evolution of the three macroeconomic variables. Agents understand that even if taxes are not raised today, they will increase in the future. This is enough to induce the dynamics typical of the Ricardian regime and sterilize the inflationary shocks of the '70s.

We regard this result as quite important. It could be argued that for an external observer the actions of the Federal Reserve are readily interpretable, while it might be harder to correctly infer the commitment of the fiscal authority to stabilize debt. In this context, the appointment of a conservative chairman would not only coincide with a change in the conduct of monetary policy, but would rather induce a shift in agents' expectations about the future resolution of the latent conflict between the monetary and fiscal authorities. As long as agents understand that the conservative chairman is implicitly forcing a change in the conduct of fiscal policy, then the dynamics of the model will coincide with the ones implied by the Ricardian regime.

5 Inflation Expectations and level of debt

Following the current crisis, the interaction between monetary and fiscal policies is likely to be remarkably important for the years ahead. A question that often arises is why we do not observe high expected inflation in face of the large stock of debt. This section is meant to illustrate that whether a large stock of debt is inflationary or not depends on agents' beliefs around the future policy makers' behavior. To illustrate this point, Figure 14 considers a series of forecasts conditional on different assumptions regarding the evolution of the monetary/fiscal policy mix. In each case the economy is assumed to be currently in the AM/PF regime. The darkest line assumes that agents are sure that the economy will remain in the AM/PF regime. As the lines become lighter and lighter agents attach larger and larger probability to entering the PM/AF regime for a prolonged period of time. The lightest line assumes that agents are convinced that eventually the Ricardian regime will be abandoned in favor of the non-Ricardian regime. As agents' confidence deteriorates, agents' expectations about future inflation become less anchored. In the limit, as agents attach probability one to exiting the Ricardian regime, inflation expectations can go up to 25%.

Notice that all the forecasts are obtained using the same starting point, the estimated end-of-the-sample DSGE state vector, and only agents' expectations are changing. This means that for a given state of the economy, very different outcomes for inflation and debt dynamics could arise depending on agents' beliefs. Bianchi and Melosi (2011) develop these ideas in detail, modeling the evolution of agents' beliefs in response to policy makers' behavior. However, even this simple exercise allows us to make two important points. First, as long as agents are certain that eventually the debt will be repaid and as long as this does not occur too far into the future, inflation will be low, even if today the level of debt is very high. Second, low expected inflation can coexist with a relatively large probability of entering a high inflation regime characterized by passive monetary policy and active fiscal policy.

6 Conclusions

This paper has shown that the rise and fall of US inflation can be explained by a switch from a non-Ricardian to a Ricardian regime. Under the two regimes, shocks propagate in very different ways. Under the non-Ricardian regime, fiscal shocks determine a long lasting and persistent increase in inflation and the monetary authority loses its ability to control inflation. However, the effects of these shocks last only as long as the non-Ricardian regime is in place: As soon as the switch to the Ricardian regime occurs, inflation drops, the economy enters a recession, and debt-to-GDP ratio starts increasing. These features characterized the events of the early '80s and can be rationalized by the regime change itself.

Using counterfactual simulations we then establish two important results. First, to the extent that the Great Inflation was caused by the way fiscal and monetary shocks propagate under the non-Ricardian regime, if agents had been confident about the regime change of the early '80s or the Ricardian regime had been in place since 1955, inflation in the '70s would not have increased. Second, given that the fall in inflation in the early '80s is explained by a regime change and not by exogenous shocks, if the switch to the Ricardian regime had not occurred, inflation would have remained above the steady state for another ten years.

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A 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:

$$\begin{aligned}\left(1+\Phi\gamma^{-1}\right)\widehat{y}_t &= \widetilde{g}_t\left(1+\Phi\gamma^{-1}-\rho_g\right)+\Phi\gamma^{-1}\left(\widehat{y}_{t-1}-\widetilde{g}_{t-1}\right)\\ &\quad -\left(1-\Phi\gamma^{-1}\right)\left[\widetilde{R}_t-E_t\left[\widetilde{\pi}_{t+1}\right]+\left(\rho_d-1\right)d_t\right]+E_t\left[\widehat{y}_{t+1}\right]+\left(\rho_a-\Phi\gamma^{-1}\right)a_t\end{aligned}$$

2. Phillips curve:

$$(1+\beta)\,\widetilde{\pi}_t=\kappa\left(1-\Phi\gamma^{-1}\right)^{-1}\left[\widehat{y}_t-\widetilde{g}_t-\Phi\gamma^{-1}\left[\widehat{y}_{t-1}-\widetilde{g}_{t-1}-a_t\right]\right]+\kappa\mu_t+\widetilde{\pi}_{t-1}+\beta E_t\left[\widetilde{\pi}_{t+1}\right]$$

3. Monetary policy rule:

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

4. Total Government purchases:

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

5. Fiscal rule:

$$\widetilde{\tau}_t = \rho_\tau \left(\xi_t\right) \widetilde{\tau}_{t-1} + \left(1 - \rho_\tau \left(\xi_t\right)\right) \left[\delta_b \left(\xi_t\right) \widetilde{b}^m_{t-1} + \delta_e \widetilde{e}_t\right] + \delta_y \left(\widehat{y}_{t-1} - \widehat{y}^n_{t-1}\right) + \sigma_\tau \epsilon_{\tau,t}$$

6. Debt:

$$\widetilde{b}^m_t = \beta^{-1} \widetilde{b}^m_{t-1} + b^m \beta^{-1} \left(\widehat{R}^m_{t-1,t} - \widehat{y}_t + \widehat{y}_{t-1} - a_t - \widetilde{\pi}_t\right) - \widetilde{\tau}_t + \widetilde{e}^S_t + \widetilde{e}^L_t + \widetilde{tp}_t$$

7. Return long term bond:

$$\widehat{R}^m_{t,t+1} = R^{-1} \rho \widehat{P}^m_{t+1} - \widehat{P}^m_t$$

8. No arbitrage:

$$R_t = E_t \left[R^m_{t,t+1}\right]$$

9. Expenditure, short term component:

$$\widetilde{e}^S_t = \rho_{e^S} \widetilde{e}^S_{t-1} + \left(1 - \rho_{e^S}\right) \phi_y \left(\widehat{y}_t - \widehat{y}^n_t\right) + \sigma_{e^S} \epsilon_{e^S,t}$$

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

$$\widetilde{e}^L_t = \rho_{e^L} \widetilde{e}^L_{t-1} + \sigma_{e^L} \epsilon_{e^L,t}$$

11. Term premium:

$$\widetilde{tp}_t = \rho_{tp} \widetilde{tp}_{t-1} + \sigma_{tp} \epsilon_{tp,t}$$

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:

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

B MCMC algorithm

When working with models whose posterior distribution is very complicated in shape it is very important to find the posterior mode. In a MS-DSGE model, this search can turn out to be an extremely time-consuming task, but it is a necessary step to reduce the risk of the algorithm getting stuck in a local peak.

Draws from the posterior are obtained using a standard Metropolis-Hastings algorithm initialized around the posterior mode:

- Step 1: Draw a new set of parameters from the proposal distribution: $\vartheta \sim N\left(\theta_{n-1}, c\overline{\Sigma}\right)$
- Step 2: Compute $\alpha\left(\theta^m;\vartheta\right)$:

  $$\alpha\left(\theta^m;\vartheta\right)=\min\left\{p\left(\vartheta\right)/p\left(\theta^{m-1}\right),1\right\}$$

  where $p\left(\theta\right)$ is the posterior evaluated at θ.
- Step 3: Accept the new parameter and set $\theta^m=\vartheta$ if $u<\alpha\left(\theta^m;\vartheta\right)$ where $u\sim U\left(\left[0,1\right]\right)$, otherwise set $\theta^m=\theta^{m-1}$
- Step 4: If $m\geq n^{sim}$, stop otherwise go back to step 1

The matrix $\overline{\Sigma}$ corresponds to the inverse of the Hessian computed at the posterior mode $\overline{\theta}$. The parameter c is set to obtain an acceptance rate of around 40%. The posterior is obtained combining the priors with the likelihood computed using the modified Kalman filter described in Kim and Nelson (1999).