

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. 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 can account for the change in the persistence and volatility of inflation.

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1 Introduction

Over the past three years the US economy has gone through one of the most severe recessions in its history, and possibly the worst one since the Great Depression. In an attempt to mitigate the effects of the recession exceptional measures have been taken by the US Government and the Federal Reserve. The stimulus package has implied a substantial increase in government expenditure and the Federal Reserve has injected a significant amount of liquidity into the market, creating an entire set of new tools to conduct monetary policy.

As a result of these important changes the debt-to-GDP ratio is expected to increase to levels that are comparable to the ones inherited after World War II. Furthermore, the relevant changes in the composition of the Fed's balance sheet has induced some economists and practitioners to wonder if the Fed's independence is at risk (Sims (2009a)). Taken together these facts have potentially important consequences for the Fed's ability to control inflation. In fact, in many of the general equilibrium models that are routinely used to analyze the effects of Central Banks' interventions, the monetary policy authority is able to control inflation only under the assumption that the fiscal authority is committed to adjusting taxes and government expenditure in order to stabilize debt. When this assumption is relaxed, existence and uniqueness of an equilibrium in a rational expectations general equilibrium model depend on the parameters characterizing the joint behavior of the monetary authority *and* the fiscal authority, as shown by Leeper (1991).

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 (3 Feb 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, the role of fiscal policy has often been neglected. The standard assumption is that the fiscal authority moves a lump-sum tax (or provides a subsidy) to balance the fiscal deficit. This is not an obvious assumption, but rather a strong one. Decisions regarding taxation and government expenditure are usually highly scrutinized by the public. Furthermore, the political process leading to tax increases is often long and subject to compromises, as the recent events regarding the

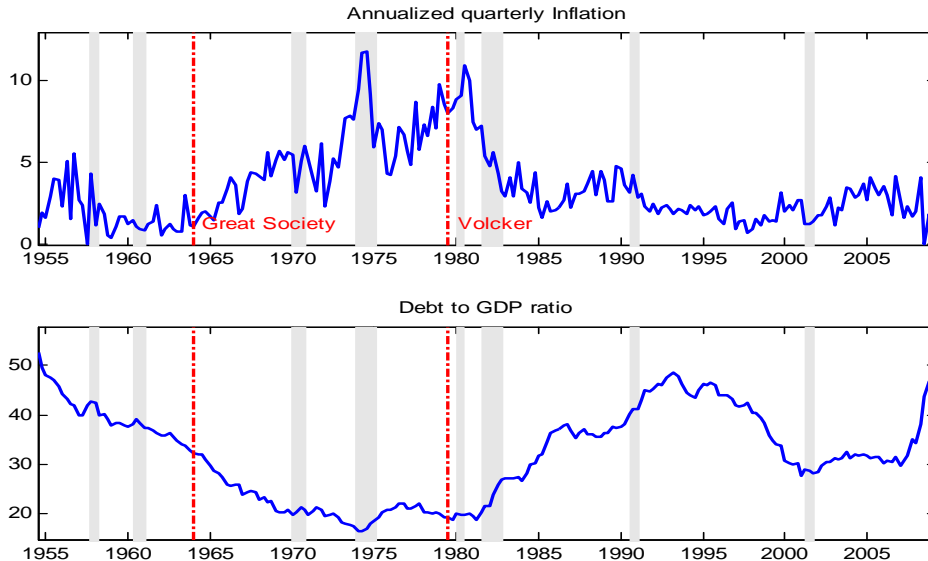


Figure 1: Annualized quarterly inflation and debt-to-GDP ratio over the sample 1954:III-2009:IV. The grey shaded areas represent the NBER recessions, while the two red vertical lines mark President Johnson’s first ever public reference to the Great Society (May 1964) and the appointment of Paul Volcker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

increase of the debt ceiling have made painfully clear. In other words, there is no reason to assume that the Government is committed to passively adjusting the fiscal instruments in order to accommodate the decisions of the monetary authority. When this commitment is absent, policy interventions can have perverse and surprising effects and government deficits can be inflationary.

This has induced economists such as Sims (2009b) and Cochrane (1998) to conjecture that the rise of inflation in the ’70s could be the result of a dysfunctional interaction between monetary and fiscal policy. In order to shed some light on the validity of this hypothesis, this paper considers a micro-founded Dynamic Stochastic General Equilibrium (DSGE) model in which the monetary/fiscal policy mix is subject to a one-time-only fully credible switch from a non-Ricardian to a Ricardian regime. The two regimes have very different implications for the way the shocks propagate through the economy. Under the non-Ricardian regime the fiscal authority is not willing to move taxes in order to keep the debt-to-GDP ratio stable. This implies that shocks that determine an acceleration of the debt-to-GDP ratio become inflationary. Notice that among these shocks, we find increases in the FFR, with the result that the monetary authority loses its ability to control inflation even if it might still be able to generate a recession in the short run. The propagation of these shocks is also

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

Figure 1 reports the evolution of inflation and debt-to-GDP ratio over the past fifty years. 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 of time the debt-to-GDP ratio has been declining smoothly. Then, in the early '80s we observe a drastic change in the dynamics of these two variables: The debt-to-GDP ratio starts increasing steadily while inflation experiences a sudden and sharp drop that coincides with two deep recessions. Since then, trend inflation has been remarkably stable and the movements in inflation have been mostly at high frequency (Stock and Watson (2007)). We find that the explanatory power of the model is maximized when the regime change occurs a few quarters after the appointment of Volcker, marked with a vertical line in the graph, and we show that the model dynamics and the timing of the regime change provide a unified theory for the stylized facts described above.

First, using counterfactual simulations in which the shocks hitting the economy are left unchanged, we show that if agents had been confident about the possibility of entering the Ricardian regime or if such a regime had been in place from the beginning of the sample, the Great Inflation would not have occurred. This is because in our model the rise in trend inflation in the '70s is explained by the interaction between a series of shocks to the long term component of government expenditure and the non-Ricardian regime that was in place at that time. Under such a regime the fiscal authority is not willing to increase taxation to keep the debt-to-GDP ratio balanced. Therefore, a shock to government expenditure determines a long lasting and slow moving increase in inflation. At the same time, the debt-to-GDP ratio experiences a drop on impact, as the result of an upward revision in short term interest rates that causes a fall in the value of long term bonds, and then it keeps declining because of the negative real interest rates. 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 assumed to be able to foresee that a regime change will eventually occur, the inflationary shocks of the '70s are sterilized and trend inflation does not rise. Furthermore, we show that the first acceleration in the long term component of government expenditure occurs around 1964, when President Johnson made the first ever public reference to the Great Society (May 1964, first vertical line in figure 1).

Second, we find that in the same way the non-Ricardian regime plays a key role in explaining the rise in inflation and the 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, while the others are left unchanged. 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 stays low and the Volcker recession is substantially mitigated.

We then use actual and counterfactual impulse responses to highlight 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. The effects of these shocks slowly propagate for a long time and reach a peak several periods after the time of the impulse. However, these 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 model.

Finally, we use the estimates obtained in the paper to analyze the current economic situation. We point out that if the economy happened to enter the non-Ricardian regime again, the consequences for inflation would be disastrous. Moreover, contrary to what may appear, the current levels for inflation expectations and long term interest rates are compatible with agents attaching a positive probability to the economy entering a period of high inflation triggered by a lack of fiscal discipline, suggesting that it would be appropriate for policymakers to lay out a clear plan to enhance fiscal sustainability. This would have at least two important positive effects. First, it would help in reducing the potential increase in inflation, given that such an increase depends on the level of debt accumulated over time. Second, it would arguably reduce the probability that agents attach to the economy entering a non-Ricardian regime. In other words, having a long term plan for handling the current level of debt would ensure that agents' expectations remains anchored even in the moment that the economic outlook appears less grim.

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), Woodford (1994), and Woodford (1995), that focus on the problem of price determinacy, and Cochrane (1998), that takes a *frictionless view* of US inflation.¹ We use some of the insights of this literature to provide an alternative explanation for the rise and fall of inflation with respect to the work of Primiceri (2006), Cogley and Sargent (2005), and Sargent et al. (2006). These authors explain the events of the '70 with models in which the beliefs of the monetary authority around the structure of the economy are evolving over time and fiscal policy does not play any explicit role. Instead, in our case the main ingredient is exactly a change in the monetary/fiscal policy mix.

To the extent that the paper provides a theory for the movements in trend inflation, our work is also related to Cogley et al. (2008) 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 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 get 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. In this paper we estimate the policy rules and the other parameters of the model jointly and, perhaps more importantly, we remove the assumption that agents are perfectly informed about the possibility of regime changes. This is the key ingredient to obtain the rise in the low frequency component of inflation during the '70s.

Finally, the paper is obviously related to the extensive literature that explores the evolution of output and inflation over the past fifty years. Clarida et al. (2000) and Lubik and Schorfheide (2004) point out that 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

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.

that time. Fernández-Villaverde and Rubio-Ramírez (2007) and Fernández-Villaverde et al. (2010) consider models with time-varying structural parameters and find substantial evidence of parameter instability. Using a large scale DSGE model augmented with stochastic volatilities, Justiniano and Primiceri (2008) find that investment shocks play a key role in explaining the changes in the reduced form properties of the economy. Davig and Doh (2008) estimate a New-Keynesian model in which structural parameters can change across regimes to assess the sources that lead to a decline in inflation persistence. Bernanke and Mihov (1998), Leeper and Zha (2003), Stock and Watson (2003), Canova and Gambetti (2004), Kim and Nelson (2004), Cogley and Sargent (2006), and Primiceri (2005) provide little evidence in favor of the view that the monetary policy rule has changed drastically. Finally, Ireland (2007), Liu et al. (2008), and Schorfheide (2005) consider models in which the target for inflation is moving over time, while in our case the target for inflation is constant and the increase in the average level of inflation is the result of shocks to government expenditure.

The content of this paper can be summarized as follows. Section 2 describes the model. Section 3 presents the main results. Section 4 considers forecasts based on different scenarios about the behavior of policymakers and agents' beliefs. Section 5 concludes.

2 The Model

We consider a new-Keynesian model augmented with a fiscal block. In some dimensions the real economy block resembles the model employed by Lubik and Schorfheide (2004).

Households

The representative household maximizes the following utility function:

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

subject to the budget constraint:

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

where D_t stands for dividends paid by the firms, C_t is consumption, h_t is hours, W_t is the real wage, T_t stands for taxes, TR_t stands for transfers, 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 $u_{d,s}$ has mean one and time series representation: $\log (d_t) = \rho_d \log (d_{t-1}) + \sigma_d \varepsilon_{d,t}$. Following Eusepi and Preston (2011) and Woodford (2001), we assume that there are two types of government debt: one-period government debt, B_t^s , in zero net supply with price P_t^s and a more general portfolio of government debt, B_t^m , in non-zero net

supply with price P_t^m . The former debt instrument satisfies $P_t^s = R_t^{-1}$. The latter debt instrument has payment structure $\rho^{T-(t+1)}$ for $T > t$ and $0 < \rho < 1$. The value of such an instrument issued in period t in any future period $t + j$ is $P_{t+j}^{m-j} = \rho^j P_{t+j}^m$. The asset can be interpreted as a portfolio of infinitely many bonds, with weights along the maturity structure given by $\rho^{T-(t+1)}$. Varying the parameter ρ varies the average maturity of debt.

Firms

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

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

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

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

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

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

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

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

Labor is the only input in a linear production function:

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

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

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

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

Here a_t can be interpreted as an aggregate technology shock. This specification determines a stochastic trend.

Government

The (linearized) total federal government expenditure as a fraction of GDP \tilde{e}_t is the sum of a short term component \tilde{e}_t^S and a long term component \tilde{e}_t^L :

$$\tilde{e}_t = \tilde{e}_t^L + \tilde{e}_t^S$$

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

The long term component is assumed to be completely exogenous and it is meant to capture the large programs that generally 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* government 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:

$$\tilde{g}_t = \rho_g\tilde{g}_{t-1} + (1 - \rho_g)\phi_{eS}\tilde{e}_{t-1}^S + \sigma_g\epsilon_{g,t} \quad (7)$$

where $\epsilon_{g,t}$ can be interpreted as a shock to Government purchases. Local governments collect a lump-sum tax to balance their own budget constraint.

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

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

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

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

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

Monetary and Fiscal Rules

The Central Bank moves the FFR according to the rule:

$$\frac{R_t}{R^*} = \left(\frac{R_{t-1}}{R^*}\right)^{\rho_R(\xi_t^{sp})} \left[\left(\frac{\Pi_t}{\Pi^*}\right)^{\psi_\pi(\xi_t^{sp})} \left(\frac{Y_t}{Y_t^n}\right)^{\psi_y(\xi_t^{sp})} \right]^{(1-\rho_R(\xi_t^{sp}))} \sigma_R e^{\epsilon_{R,t}} \quad (8)$$

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

rule:

$$\tilde{\tau}_t = \rho_\tau (\xi_t^{sp}) \tilde{\tau}_{t-1} + (1 - \rho_\tau (\xi_t^{sp})) \left[\delta_b (\xi_t^{sp}) \tilde{b}_{t-1}^m + \delta_e \tilde{e}_t \right] + \delta_y (\hat{y}_{t-1} - \hat{y}_{t-1}^n) + \sigma_\tau \epsilon_{\tau,t} \quad (9)$$

where $\tilde{\tau}_t$ is the level of tax revenues with respect to GDP in linear deviations from the steady state ($\tau_t = T_t / (P_t Y_t)$), \tilde{b}_{t-1}^m is the linear deviation of debt from the steady state and $\epsilon_{\tau,t}$ is an i.i.d. shock. Note that taxes respond to the total level of expenditure. This is to allow for the possibility that even if the response to debt is not large enough to guarantee a passive fiscal regime, the Government still reacts positively to increases in expenditure. In other words, we do not force news about future government expenditure to be necessarily inflationary under the non-Ricardian regime.

In equations (8) and (9), ξ_t^{sp} 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 $j = 1, \dots, m^{sp}$ and follows a Markov chain that evolves according to a transition matrix H^{sp} . We assume a lower triangular structure for the transition matrix to capture the possibility of a one-time-only change in the behavior of policymakers. The target for inflation and debt are assumed to be constant over time. 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 central banks 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 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:

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

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:

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

6. Debt:

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

7. Return long term bond:

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

8. No arbitrage:

$$R_t = E_t [R_{t,t+1}^m]$$

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" (this is used to close the gap in the law of motion for debt):

$$\tilde{t}p_t = \rho_{t^p} \tilde{t}p_{t-1} + \sigma_{t^p} \epsilon_{t^p,t}$$

12. Technology:

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

| | 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).

13. Demand shock:

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

14. Mark-up shock:

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

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:

$$\Gamma_0(\xi_t^{sp}, \theta) S_t = \Gamma_1(\xi_t^{sp}, \theta) S_{t-1} + \Psi(\xi_t^{sp}, \theta) Q \epsilon_t + \Pi \eta_t \quad (10)$$

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

2.2 Determinacy Regions and Agents' Information Set

Following Leeper (1991), we can distinguish four regions of the parameter space according to the existence/uniqueness of a solution to the model. These regions are summarized in table (1). 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 fiscal policy is Ricardian because the fiscal authority moves taxes in order to keep the process for debt stable. We can think of fiscal policy as passive to the extent that is *passively* accommodate the behavior of the monetary authority. We will sometimes refer to the regime associated with this region as the *standard* regime. The second determinacy region (Passive Monetary/Active Fiscal (PM/AF)) is less familiar and corresponds to the case in which the monetary authority is relatively unresponsive to fluctuations in inflation, while the fiscal authority does not respond strongly enough to movements in the debt-to-GDP ratio. This regime, if taken in isolation, does not imply Ricardian equivalence and even in absence of distortionary taxation fiscal shocks can have an impact on inflation and output. We will sometimes refer to the regime associated with this region with *flipped* regime. Finally, when both authorities behave independently (AM/AF) no equilibrium exists, whereas when both of

them are passive (PM/PF) the economy is subject to multiple equilibria.

In applied work, a lot of attention has been devoted to the *standard* determinacy region and to the problem of indeterminacy (see Lubik and Schorfheide (2004)), whereas the flipped 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 can play in explaining low frequency movements in inflation. Our benchmark model allows for a one-time-only, fully credible regime change from the flipped equilibrium to the standard equilibrium. Consistent with this assumption, we assume that when agents observe a regime in place, they expect this regime to prevail forever. This implies that the solution for each regime can be obtained with standard solution methods for rational expectations general equilibrium models (in our case, we are going to use Sims (2002)'s solution method).

Alternatively, we could consider a model in which the economy never entered the flipped regime, but agents attach a positive probability to this event occurring and then staying there for a prolonged period of time. If the probability is high enough, the effects of fiscal shocks would be very similar to the ones that characterize the flipped regime itself. Furthermore, Bianchi and Melosi (2011) show that the model presented here approximates the dynamics of an economy in which agents have to learn about the persistence of the PM/AF regime and have observed such a regime for a prolonged period of time. 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.

3 Estimates

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

$$S_t = T(\xi_t^{sp}, \theta^{sp}) S_{t-1} + R(\xi_t^{sp}, \theta^{sp}) Q \epsilon_t \quad (11)$$

When agents are not aware of regime changes the law of motion depends exclusively on the parameters characterizing the regime that is in place at time t . Instead, when agents are aware of regime changes, the parameters under the alternative regimes and the probabilities of moving across regime become remarkably important. This feature will allow us to conduct

some interesting counterfactual simulations in section 3.2.

From now on, a more compact notation will be used: $T(\xi_t^{sp}) = T(\xi_t^{sp}, \theta^{sp})$ and $R(\xi_t^{sp}) = R(\xi_t^{sp}, \theta^{sp})$.

The law of motion (11) can be combined with a system of observation equations. The result is a model cast in state space form:

$$Y_t = D(\theta^{sp}) + ZS_t \quad (12)$$

$$S_t = T(\xi_t^{sp}) S_{t-1} + R(\xi_t^{sp}) Q\epsilon_t \quad (13)$$

$$\epsilon_t \sim N(0, I) \quad (14)$$

$$H^{sp} = \begin{bmatrix} p_{11} & 0 \\ p_{21} & 1 \end{bmatrix} \quad (15)$$

where Y_t is a vector containing the observables, D is a column vector containing the steady state values, Z is a matrix mapping the Markov-switching law of motion (13) into the observables. The likelihood is computed using the modified Kalman filter described in Kim and Nelson (1999a) 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 A for more details.

The vector Y_t contains seven observables: real GDP growth rate, annualized GDP deflator quarterly inflation, annualized quarterly FFR, 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 (see, among others, Leeper et al. (2009)). 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.

| | Posterior | | | | Prior | | |
|---------------------------|-----------|---------|---------|---------|-------|------|---------|
| | Mode | Mean | 5% | 95% | | Mean | Std Dev |
| $\psi_\pi(\xi^{sp} = 1)$ | 0.6244 | 0.6115 | 0.4298 | 0.7873 | G | 0.80 | 0.30 |
| $\psi_\pi(\xi^{sp} = 2)$ | 2.3522 | 2.3860 | 2.0117 | 2.8034 | N | 2.50 | 0.50 |
| $\psi_y(\xi^{sp} = 1)$ | 0.3716 | 0.3844 | 0.2543 | 0.5369 | G | 0.25 | 0.15 |
| $\psi_y(\xi^{sp} = 2)$ | 0.1527 | 0.1642 | 0.1042 | 0.2386 | G | 0.25 | 0.15 |
| $\rho_R(\xi^{sp} = 1)$ | 0.8480 | 0.8506 | 0.8010 | 0.8939 | B | 0.50 | 0.20 |
| $\rho_R(\xi^{sp} = 2)$ | 0.8132 | 0.8188 | 0.7756 | 0.8607 | B | 0.50 | 0.20 |
| $\delta_b(\xi^{sp} = 1)$ | 0 | — | — | — | F | — | — |
| $\delta_b(\xi^{sp} = 2)$ | 0.0327 | 0.0369 | 0.0214 | 0.0585 | G | 0.07 | 0.02 |
| $\rho_\tau(\xi^{sp} = 1)$ | 0.7306 | 0.7292 | 0.6537 | 0.7985 | B | 0.50 | 0.20 |
| $\rho_\tau(\xi^{sp} = 2)$ | 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_{eS} | 0.4700 | 0.4732 | 0.3858 | 0.5566 | B | 0.20 | 0.05 |
| ϕ_{eS} | 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 |
| $100\sigma_{eS}$ | 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 |
| $100\sigma_{eL}$ | 0.1 | — | — | — | F | — | — |

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

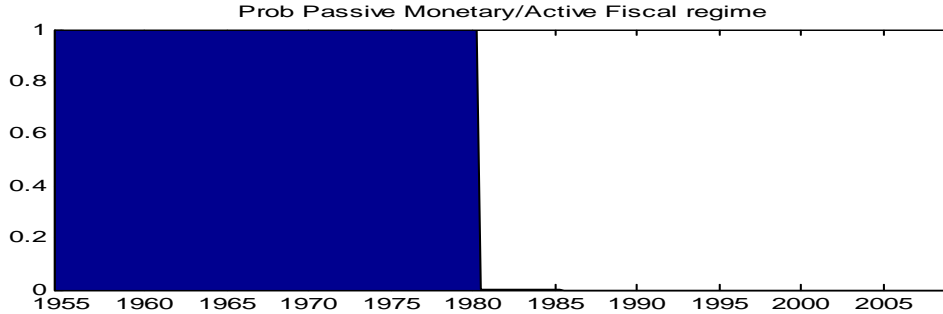


Figure 2: Probability of the PM/AF non-Ricardian regime at the posterior mode.

3.1 Parameters estimates and regime probabilities

The priors for the parameters that do not move across regimes are in line with previous results in the literature and are relatively loose, except for the steady state level of debt. The priors on the stochastic volatilities are quite 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 substantially restricted to being 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. Finally, we fix the annualized steady state level of inflation π^* to 2% and the discount factor β to .9985.

Regarding the parameters of the Taylor rule, under the AM/PF regime ($\xi_t^{sp} = 1$) 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. The degree of interest rate smoothing turns out to be larger under the AM/PF regime. As for the other parameters, the low value of the slope of the Phillips curve ($\kappa = 0.0128$) is particularly relevant, since such a small value implies a very high sacrifice ratio. In other words, in order to bring inflation down the Federal Reserve needs to generate a severe recession.

While the features of the two regimes are in part induced by the priors, 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. In this respect, the results are similar to the ones obtained by Bianchi (2011). However, here we are assuming that the entire monetary/fiscal policy combination is changing, not just the behavior of the monetary authority. As shown below, this is going to be important in understanding the rise and subsequent decline in inflation.

3.2 Counterfactual analysis

When working with models that allow for regime changes it is interesting to simulate what would have happened had regime changes not occurred, or had they occurred at different points in time, or had they occurred when they otherwise did not. 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 to address the effects of fundamental changes in the policy regime. 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 Volcker disinflation. 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.²

²The results are substantially unchanged when the shocks to monetary and fiscal policy are kept unchanged. We decide to remove them because these shocks are arguably strictly related to the rules in place.

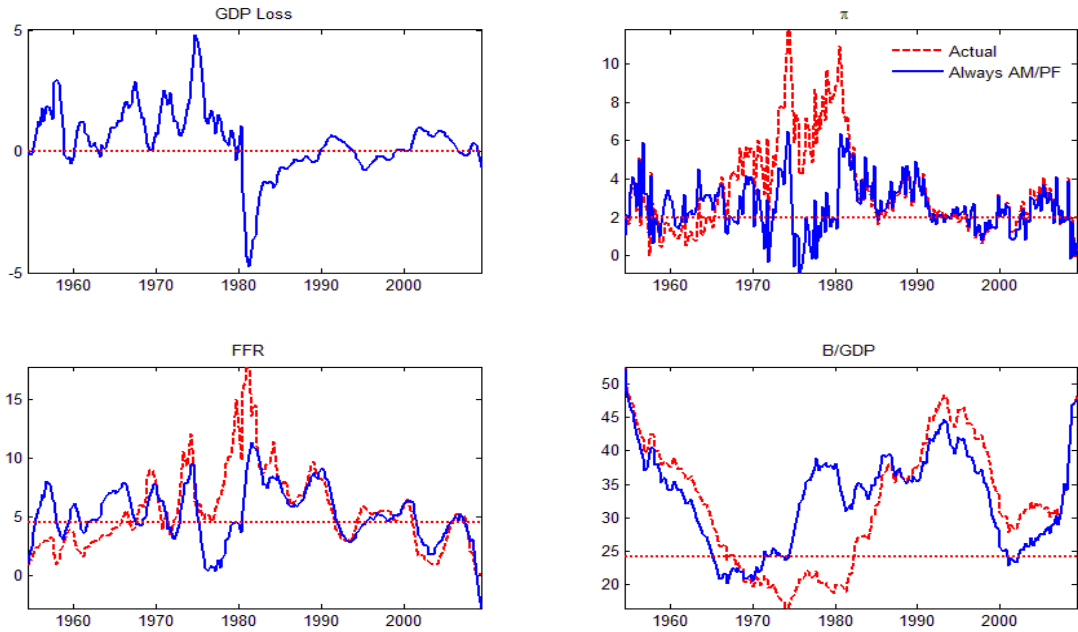


Figure 3: The Great Inflation: Counterfactual simulation in which all non-policy shocks are left unchanged and the Ricardian regime is assumed in place throughout the entire sample.

Figure 3 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 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 in trend inflation and the decline in the debt-to-GDP ratio observed during the '70s. As section 3.3 makes clear, the joint behavior of inflation and debt in the '70s can be explained by the behavior of the economy in response to shocks to the long term component of government expenditure under the non-Ricardian regime. When this regime is

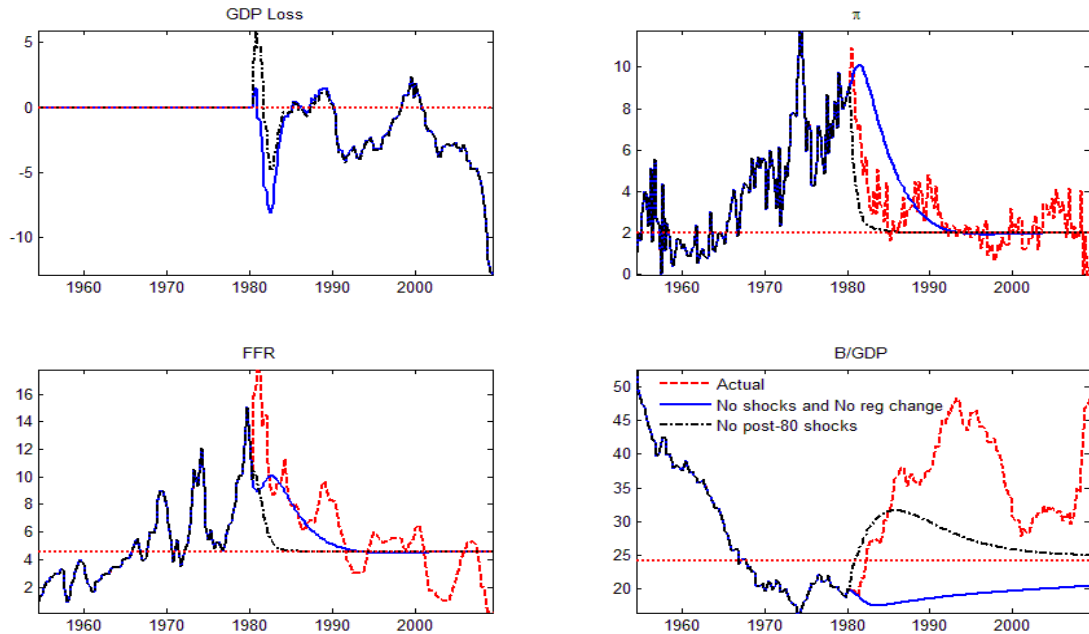


Figure 4: The Volcker Disinflation: Countefactaul simulation setting all the post regime shocks to zero. Two cases are considered. In the first case the regime change is kept (dashed-dotted black line), while in the second one the regime is removed (solid blue line).

in place, expenditure shocks are inflationary and lead to a decline in the debt-to-GDP ratio, while when the standard equilibrium prevails, the shocks are sterilized, inflation is unaffected and debt rises. Therefore, when we change the behavior of policymakers, the shocks that led to the increase in inflation in the estimates lose their effect.

3.2.2 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 disinflation, the large recession, and the turnaround in the dynamics of debt. 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 keeping the non-Ricardian regime in place over the rest of the entire sample. Figure 4 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 enable us to match three other important stylized facts observed during the early '80s: The sudden drop in inflation, the large recession associated with the Volcker disinflation, and the sudden change in the dynamics of debt. The timing is then consistent with the view of Goodfriend and King (2005) who argue 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.

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. In order to do this, we assume that when agents are under the non-Ricardian regime, they attach a 5% probability to moving to the AM/PF regime and stay there forever. In other words, agents know that they will eventually 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 when forming expectations. Therefore, the transition probabilities and characteristics of the different regimes have an impact on the law of motion in place today.

Figure 5 contains the output loss and the counterfactual and actual series for inflation, FFR, and debt-to-GDP ratio. Inflation would have been moving around the steady state during the '70s, without substantial increases in the FFR. Inflation still shows high frequency movements as the result of mark-up shocks, but we don't observe the slow moving and 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

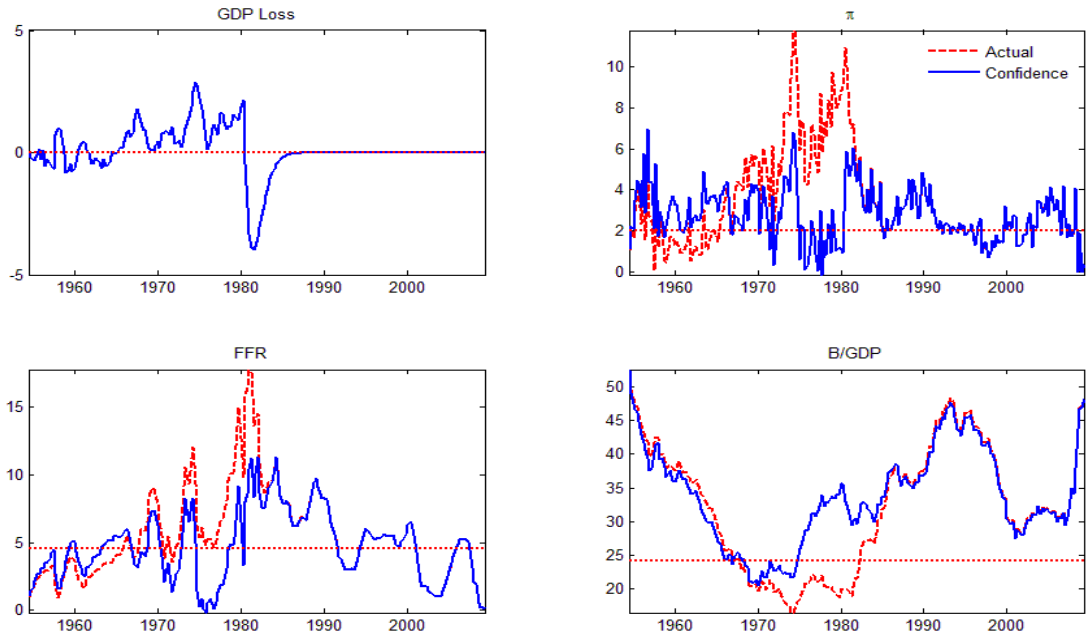


Figure 5: Confidence: Counterfactual simulation in which all non-policy shocks and regime sequences are left unchanged, but agents are confident that a switch to the Ricardian regime will eventually occur.

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 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 shows a behavior similar to the one uncovered in the first counterfactual and starts increasing well before the '80s. On the other hand, it is possible to notice a difference during the '60s as a result of the fact that taxes are still unresponsive to the high level of debt.

Summarizing, this counterfactual simulation has made an important point: If in the '70s agents had been aware of 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. To the extent that agents' beliefs play an important role in general equilibrium models with regime changes, this result resembles what was obtained in Bianchi (2011) when considering changes in monetary policy. However, as section 3.3 explains, when the entire fiscal/monetary policy bundle changes, the effects are more pervasive than when the change regards monetary policy only and agents' beliefs

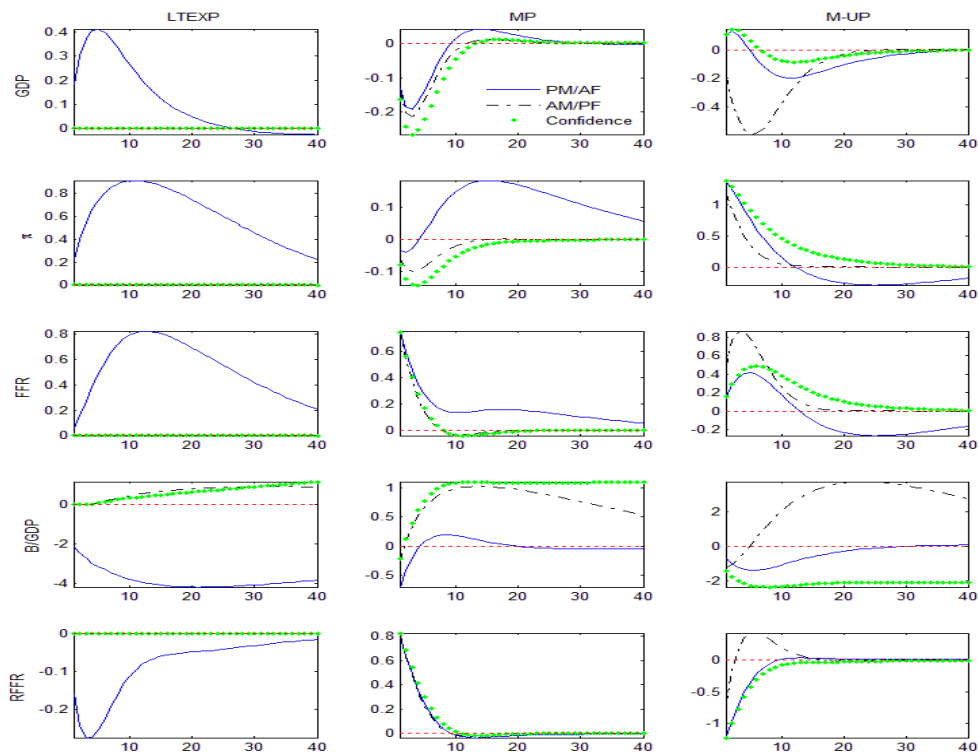


Figure 6: The three columns report the impulse responses to a long term component expenditure shock, a monetary policy shock, and a mark-up shock. Three cases are considered: PM/AF, AM/PF, and the confidence counterfactual in which the economy is under the PM/AF regime but agents expect to eventually enter the AM/PF regime.

can completely overturn the effects of the interaction between policymakers' behavior and shocks, instead of simply mitigating them.

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 the propagation of some important shocks is affected by changes in the behavior of policymakers or in agents' beliefs around these changes. 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 PM/AF to the AM/PF regime in order to shed light on the events of the early '80s.

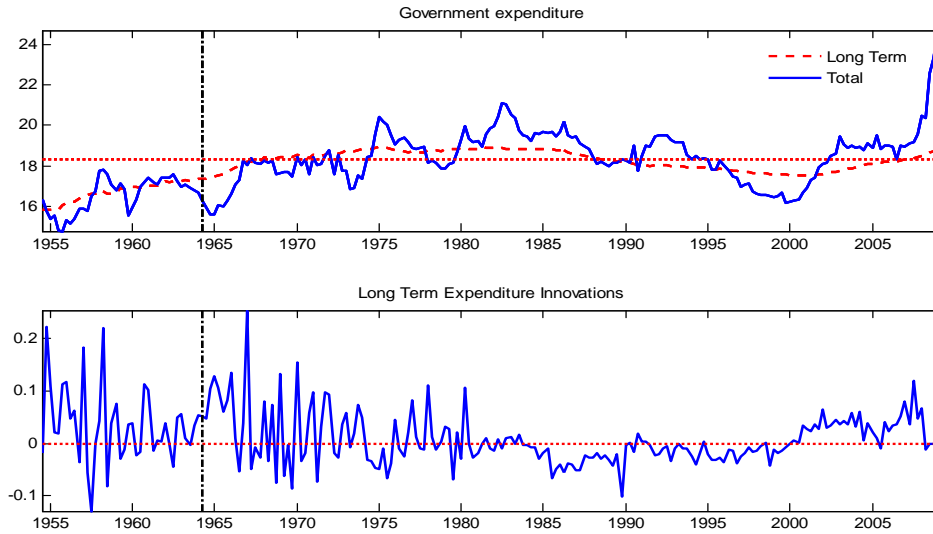


Figure 7: The top panel contains total government expenditure as a fraction of GDP and its filtered long term component. The horizontal line represents the steady state value. The lower panel reports the innovations to the long term component. The vertical bar marks the President Johnson’s first ever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

3.3.1 Monetary/Fiscal Policy Mix and Agents’ Beliefs

Figure 6 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: AM/PF (dashed black line) and PM/AF (solid blue line). The third one is based on the confidence counterfactual of subsection 3.2.3, i.e. assuming that the economy is under the PM/AF regime, but also that agents are confident that a one-time-only regime change will eventually occur and they attach 5% probability to this event for the next period. The impulse responses are computed conditional on being in a particular regime for $T = 40$ quarters. However, in the case of the beliefs counterfactual impulse response, it is important to keep in mind that the probability of the regime change affects the law of motion of the economy.

Government expenditure, Inflation, and Agents’ Beliefs

The first column reports the responses to a shock to the long run 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 starts taking effect, while under the PM/AF regime we observe a sudden drop, due to higher expected future short term interest rates, and then a smooth decline as a result of the high inflation. On the other hand, these effects disappear when agents anticipate the change in the policy mix: Under the confidence counterfactual Ricardian equivalence holds and 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 (2009b)) 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 taxation rule in place at the time of the shock determines an increase in the debt-to-GDP ratio that could appear to be "permanent" to an external observer. What matters is that agents remain confident about the long run commitment to increase taxes in order to repay debt.

The impulse responses shown so far help us in understanding the results obtained using the counterfactual simulations. First, they show that the rise in trend inflation can be explained by a lack of fiscal discipline that made a series of shocks to the long term component of government expenditure 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 resembles what we 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. These patterns disappear following the appointment of Volcker. Second,

they highlight why, when the Ricardian regime is imposed over the entire sample or agents are confident about the possibility of moving to such a regime, the increase in trend inflation practically disappears: In both cases, the expenditure 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. In the confidence counterfactual instead 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 reverse the effects of the current policymakers' behavior.

Given the important role played by long term expenditure, it is important to document that the model does not imply any unrealistic behavior for this variable. The top panel of figure 7 reports the model implied long term component of expenditure,³ 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 first acceleration in the long term component occurs around the first President Johnson's first ever public reference to the 'Great Society' that took place during a speech on May 7, 1964 and that is marked by the vertical black line in the graph.

Mark-up shocks

It is important to point out that the confidence counterfactual responses do not have to be similar to the AM/PF ones across all dimensions. For this reason, the third column displays the responses to a mark-up shock. Given the nature of the shock, it is not surprising that 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 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 expected regime change.

³The series is obtained filtering the data at the posterior mode.

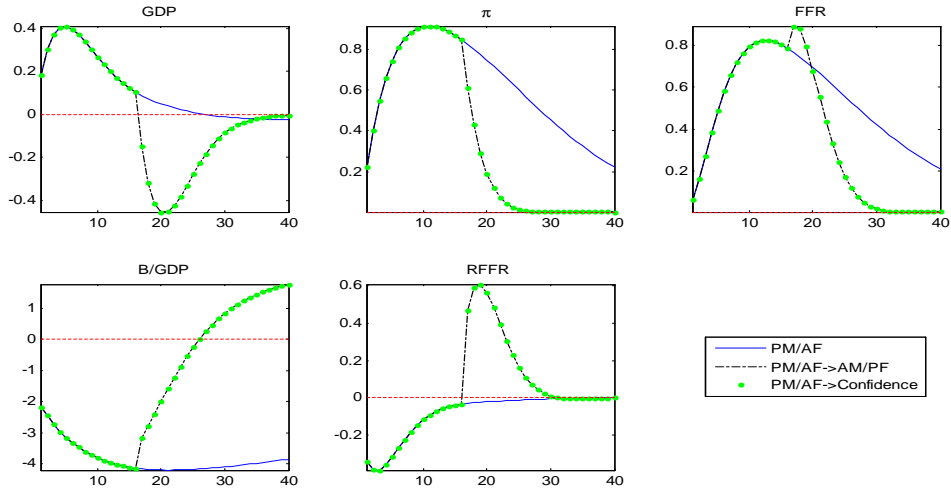


Figure 8: Impulse responses to a one standard deviation increase in the long term component of government expenditure. The solid blue line represents the case in which the economy is constantly under the PM/AF regime, the black dashed line assumes that after four years an unexpected fully credible switch to the AM/PF regime occurs, while the green dotted line assumes that the switch is replaced to an announcement that with 5% probability the change 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 the regime change is replaced with the announcement that starting from that moment there is a 5% probability (in every period) that the economy will enter such a regime. This last case corresponds to the confidence counterfactual.

The benchmark case that assumes no change in the monetary/fiscal policy mix has been discussed before: Following the initial shock, inflation starts increasing at a faster rate compared to the FFR, determining a decline in the real interest rate that in turns causes an increase in GDP. As for the debt-to-GDP ratio, on impact we observe a sudden and fairly large drop due to the decline in the price of long term bonds. Then, the variable keeps declining smoothly, because of the low real interest rates. As mentioned before, the shock seems to capture remarkably well the comovements of inflation, debt, and real interest rates that characterize the '70s.

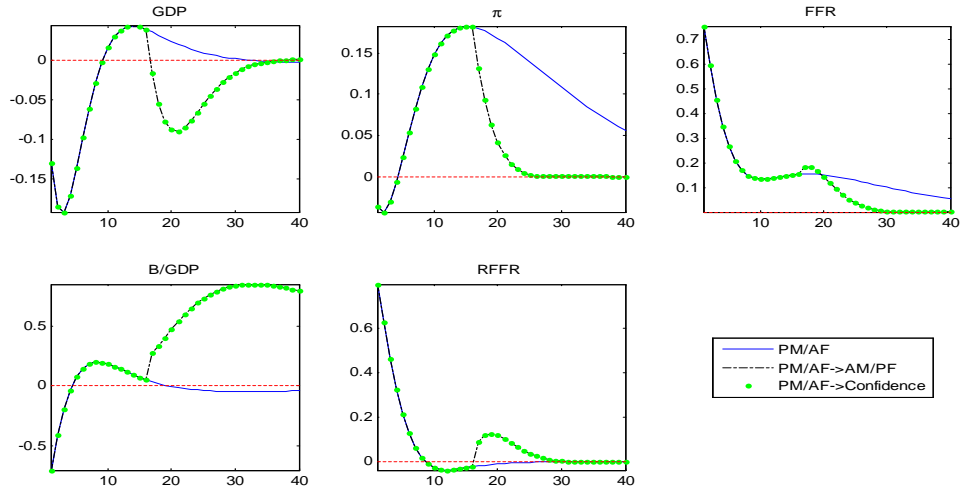


Figure 9: Impulse responses to a one standard deviation increase in the long term component of government expenditure. The solid blue line represents the case in which the economy is constantly under the PM/AF regime, the black dashed line assumes that after four years an unexpected fully credible switch to the AM/PF regime occurs, while the green dotted line assumes that the switch is replaced by an announcement that with 5% probability the change will occur.

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. These two events in turn 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 changes the impact of the shocks that occurred in the '70s. Suddenly, a series of shocks to government expenditure 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 switch in the monetary/fiscal policy combination determines a switch in the effectiveness of monetary policy, as figure 8 illustrates. As explained in section 3.3.1, under the PM/AF equilibrium the monetary policy shock determines only an initial

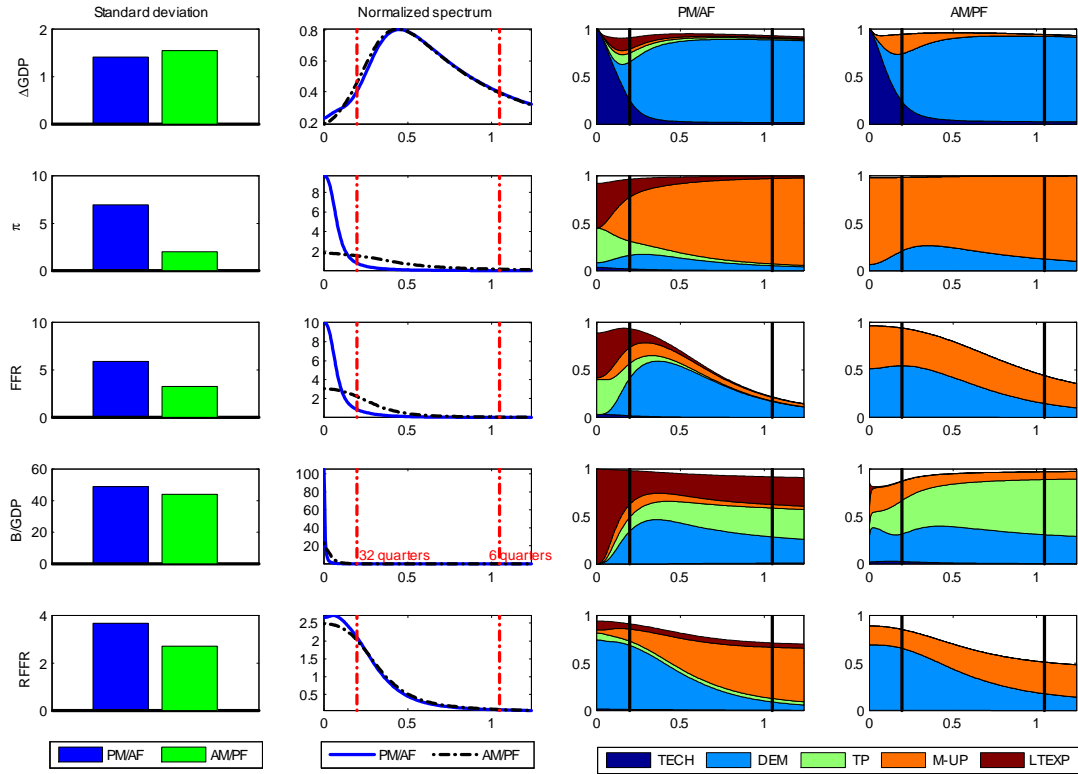


Figure 10: The figure contains the model implied standard deviations under the two regimes (first column), the normalized spectrum for the two regimes (second column), and the variance decomposition in the frequency domain under the PM/AF regime (third column) and the AM/PF regime (fourth column). All results are computed at the posterior mode and the vertical bars mark the business cycle frequencies (between 6 and 32 quarters).

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 sudden 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 Variance decomposition

Figure 10 contains results for the variance decomposition at the posterior mode. The four columns contain, respectively, the standard deviations under the two regimes, the normalized spectrum for the two regimes, and the variance decomposition in the frequency domain under the PM/AF regime and the AM/PF regime. 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 flipped to the standard 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 a significant fraction of the low frequency movements in inflation is explained by shocks to the long term component of government expenditure, while the business cycle frequencies are especially affected by mark-up shocks. In other words, according to our results movements in trend inflation can be explained by fiscal shocks when Ricardian equivalence does not hold. 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 can have an impact on inflation dynamics if Ricardian equivalence does not hold. This is an interesting point, especially in light of the recent downgrade of US debt and the debt crisis in Europe. However, at this stage we are not explicitly modeling the term premium, 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.

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 results. First, under the PM/AF regime long term expenditure shocks affect both low and high frequency movements. The high frequency contribution reflects the revaluation effects that follow a long term expenditure shock. Second, even in this case long term expenditure shocks become much less important once the AM/PF regime is in place, implying that the importance of this shock does not derive exclusively from the direct impact of expenditure on the law of motion of the government budget constraint.

The volatility of output growth goes up when moving to the AM/PF regime. This is

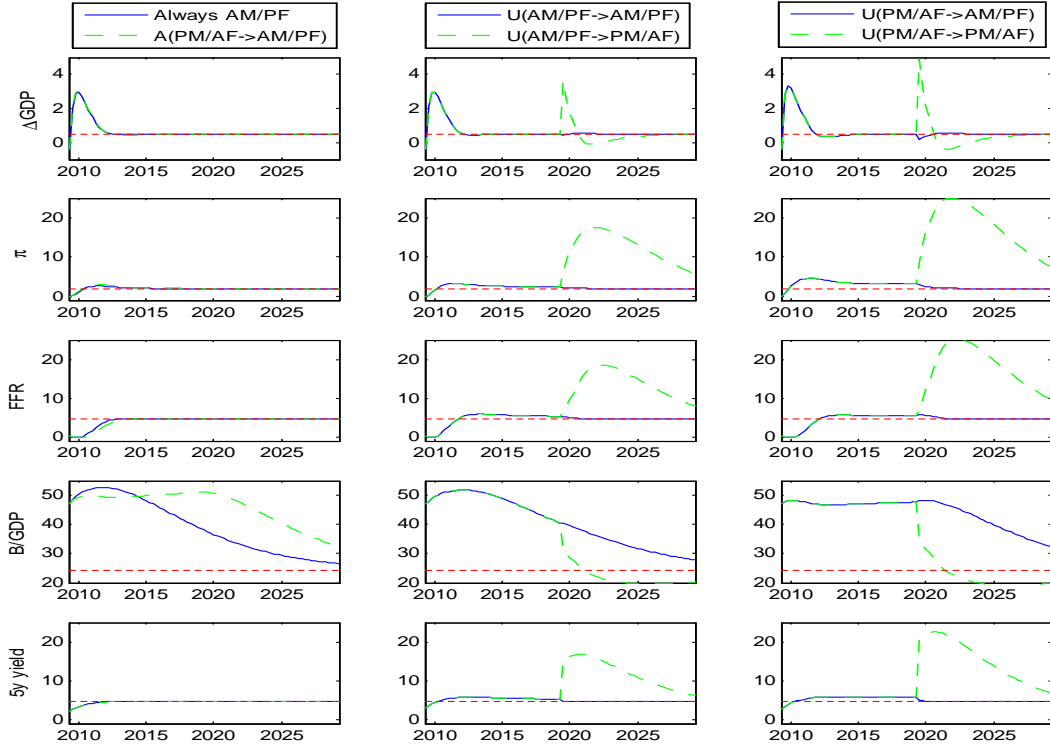


Figure 11: Conditional forecasts

not necessarily surprising, given that the Central Bank responds to the output gap and not to output growth itself. 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. However, now their contribution is mostly at business cycle frequencies, suggesting that a clear commitment to a well understood fiscal plan might help in reducing business cycle fluctuations.

4 Where is the US economy heading?

This last section contains some considerations about the current economic situation and different scenarios about the exit strategy. The model considered in this paper does not allow for unconventional monetary policy and this is certainly a limitation when analyzing the current economic situation. Nevertheless, because of the high level of debt and the

recent debate surrounding the increase of the debt ceiling, the interaction between monetary and fiscal policy is likely to be remarkably important for the years ahead. Furthermore, this section will show that the current behavior of inflation expectations and long term interest rates is not necessarily inconsistent with the possibility of the economy moving to an absorbing non-Ricardian regime of the kind that this paper has analyzed.

Figure 11 shows 20-year ahead forecasts based on four different scenarios regarding the behavior of policymakers and agents' beliefs. When the forecast involves the possibility of a regime change, it is assumed to happen after ten years. In each column, the last row reports the five years long term interest rate computed by taking into account the possibility of regime changes.

We shall start with two optimistic scenarios, both reported in the first column. The first forecast assumes the AM/PF equilibrium to be in place over the entire sample, while the second one consider a situation in which the economy is in the PM/AF regime, but agents are *confident* that the economy will eventually enter the AM/PF regime. Notice how the two scenarios have very similar predictions. The only detectable difference lies in the behavior of the debt-to-GDP ratio, given that under the PM/AF regime taxes are not increased in order to restore equilibrium. As it should be clear by now, what prevents inflation from rising is the expectation that eventually a regime change will occur. In the simulation reported here, the switch to the AM/PF regime occurs after 10 years and is reflected in the behavior of government debt.

The second and third columns consider the possibility that agents are uncertain about the future behavior of policymakers. This seems to be a reasonable scenario, especially considering the harsh debate surrounding the measures that should be adopted in order to put the debt-to-GDP ratio on a sustainable path. The two columns differ according to the regime that is in place at the beginning of the simulation: In the second column, the economy is currently in the AM/PF regime, whereas in the third column the regime that prevails today is the PM/AF regime. In the two cases, agents face the same kind of uncertainty about the regime that will prevail in the long run. With 80% probability the economy will still be in this *limbo*, with 19% probability the economy will enter an absorbing AM/PF state and with 1% probability an absorbing PM/AF regime will prevail. Notice that once the economy enters one of the two absorbing states, uncertainty gets resolved, implying a drastic change in expectations even if the absorbing state implies the same policy mix that is in place before the switch.

For each simulation, the dashed green line contemplates a switch to the absorbing non-Ricardian equilibrium, while the solid blue line corresponds to the case in which the economy happens to enter the standard Ricardian equilibrium. The first notable result consists of

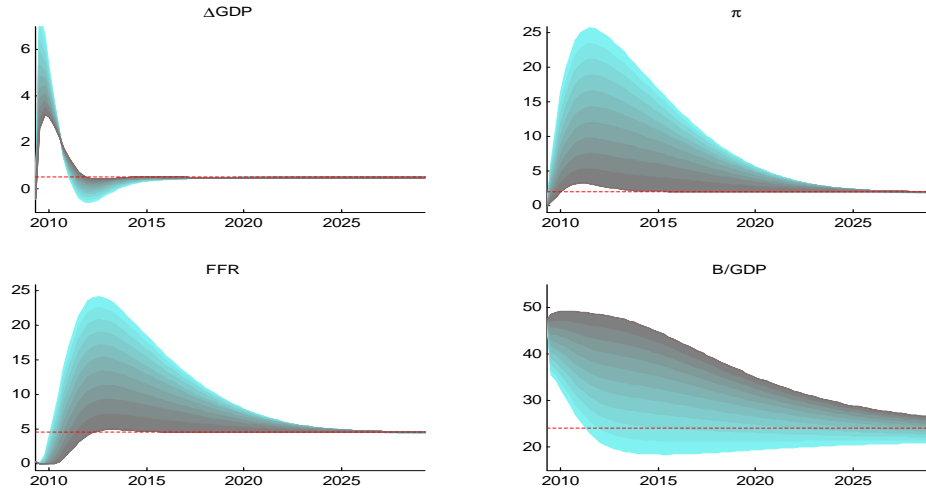


Figure 12: The figure reports expectations for GDP growth, inflation, FFR, and debt-to-GDP ratio conditional on different agents' beliefs regarding the evolution of the monetary/fiscal policy mix. Specifically, in each case the economy is currently in the PM/AF regime, the darkest line assumes that agents are confident that the economy will enter the AM/PF regime and as the lines become lighter and lighter agents become more and more pessimistic about such an event occurring. The lightest line assumes that agents attach no probability to such regime change.

the dynamics of the long term interest rate and inflation: *As long as agents are subject to uncertainty regarding the way policymakers will deal with the high level of debt, inflation and long term interest rates will remain low and close to the steady state level.* The second important result is that *this does not rule out the possibility of large shifts in inflation*, as is well illustrated by the large movements observed in the case in which the economy enters the PM/AF state. Notice that in the simulation the relative likelihood of this event is not negligible: Conditioning on the resolution of uncertainty, the probability is 5%. Nevertheless, today's long term interest rates are low. The third result consists of noticing the importance of policymakers' current behavior. As long as uncertainty lasts, or in the case in which eventually the economy enters the Ricardian regime, the current behavior of policymakers turns out to be *irrelevant*. However, if the economy happens to switch to the PM/AF regime, the jump in inflation will depend on the level of the debt-to-GDP ratio inherited from the past and consequently on the regime that has been in place until that point. Therefore, simply looking at market expectations might generate an erroneous belief that the economy is in a safe area and that today's actions won't bear any consequences.

In fact, delaying the resolution of uncertainty might also have another undesirable conse-

quence: A drift in agents expectations. Figure 12 replicates the previous exercise for different assumptions on agents' beliefs regarding the evolution of the monetary/fiscal policy mix. Specifically, in each case the economy is assumed to be currently in the PM/AF regime, but regime changes are possible and agents are aware of that. Now expectations are not computed conditional on a particular path, but taking into account all possible outcomes. The darkest line assumes that agents are sure that eventually the economy will enter the AM/PF regime, while as the lines become lighter and lighter agents become more and more pessimistic about such an event occurring. The lightest line assumes that agents attach no probability to moving to the Ricardian regime. As agents' confidence deteriorates, agents' expectations about future inflation become less anchored. In the limit, as agents attach probability zero to moving to 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. To the extent that policymakers care about providing a stable anchor for agents' expectations, outlining a credible plan for fiscal consolidation might greatly reduce the possibility of large swings in agents expectations. Furthermore, if the level of debt were scaled up to reflect its 2011 level, the swings in inflation expectations would be even more pronounced.

Summarizing, four lessons can be taken from this last section. First, as long as agents are certain that eventually the debt will be repaid and as long as this does not occur too far in the future, inflation will be low, even if today monetary policy is passive and fiscal policy is active. Second, low long term interest rates and 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. Third, if agents are uncertain about the future monetary/fiscal policy mix, the government might still be able to control inflation. Finally, any delay in cutting the debt-to-GDP ratio might have dramatic effects on the behavior of inflation if the economy happens to enter the flipped equilibrium or if agents start believing that this is the most likely scenario.

5 Conclusions

This paper has shown that the rise and fall in inflation during the '70s and early '80s 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, increases in the long term component of government expenditure determine a long lasting

and persistent increase in inflation, while 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. The model uses these dynamics to explain the events of the early '80s.

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.

Finally, we have used the model to establish two important results regarding the current economic situations. First, the low levels of inflation expectations and long term interest rates currently observed in the US do not imply that agents are certain that the Ricardian regime that has dominated the past 30 years will be in place forever. Instead, low expected inflation and moderate long term interest rates can be obtained even if agents attach a significant positive probability to moving to the non-Ricardian regime. Second, if the US economy happened to enter the non-Ricardian regime in the near future, the increase in inflation would be comparable, if not larger, to the one observed in the '70s. Furthermore, the size of the increase will depend on the amount of debt accumulated over time. Therefore, a clear plan for long run fiscal sustainability. would be particularly desirable given that it would anchor agents' expectations by reducing the probability of entering the non-Ricardian regime and mitigating the consequences of such an event.

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A Posterior mode, MCMC, and approximation of the likelihood

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 because of the solution methods and the likelihood approximation involved. A simple way to reduce the computational time consists of using a block optimization over two distinct subsets of parameters: The first includes those parameters that affect the solution of the model (structural parameters), the second collects all of the remaining parameters (volatilities and their transition matrix). In this way, the number of times the model has to be solved is substantially reduced. To take into account that some of the structural parameters are likely to co-vary with the stochastic volatilities, a completely random set of parameters is periodically selected.

A.1 MCMC

A.2 Kim's approximation of the Likelihood

In this section Kim's approximation of the likelihood (Kim and Nelson (1999b)) is described. Combine the MS states of the structural parameters and of the heteroskedastic shocks in a unique chain, ξ_t . ξ_t can assume m different values, with $m = m^{sp} * m^{vo}$, and evolves according to the transition matrix $H = H^{sp} \otimes H^{vo}$. For a given set of parameters, and some assumptions about the initial DSGE state variables and MS latent variables, we can recursively run the following filter:

$$\begin{aligned} S_{t|t-1}^{(i,j)} &= T_j S_{t-1|t-1}^i \\ T_j &= T(\xi_t = j) \end{aligned}$$

$$\begin{aligned} P_{t|t-1}^{(i,j)} &= T_j P_{t-1|t-1}^i T_j' + R_j Q_j R_j' \\ Q_j &= Q(\xi_t = j), R_j = R(\xi_t = j) \end{aligned}$$

$$\begin{aligned} e_{t|t-1}^{(i,j)} &= y_t - D - Z S_{t|t-1}^{(i,j)} \\ f_{t|t-1}^{(i,j)} &= Z P_{t|t-1}^{(i,j)} Z' + U \end{aligned}$$

$$\begin{aligned}
S_{t|t}^{(i,j)} &= S_{t|t-1}^{(i,j)} + P_{t|t-1}^{(i,j)} Z' \left(f_{t|t-1}^{(i,j)} \right)^{-1} e_{t|t-1}^{(i,j)} \\
P_{t|t}^{(i,j)} &= P_{t|t-1}^{(i,j)} - P_{t|t-1}^{(i,j)} Z' \left(f_{t|t-1}^{(i,j)} \right)^{-1} Z e_{t|t-1}^{(i,j)}
\end{aligned}$$

At end of each iteration the $M \times M$ elements of $S_{t|t}^{(i,j)}$ and $P_{t|t}^{(i,j)}$ are collapsed into M elements which are represented by $S_{t|t}^j$ and $P_{t|t}^j$:

$$\begin{aligned}
S_{t|t}^j &= \frac{\sum_{i=1}^M \Pr [\xi_{t-1} = i, \xi_t = j | Y_t] S_{t|t}^{(i,j)}}{\Pr [\xi_t = j | Y_t]} \\
P_{t|t}^j &= \frac{\sum_{i=1}^M \Pr [\xi_{t-1} = i, \xi_t = j | Y_t] \left(P_{t|t}^{(i,j)} + \left(S_{t|t}^j - S_{t|t}^{(i,j)} \right) \left(S_{t|t}^j - S_{t|t}^{(i,j)} \right)' \right)}{\Pr [\xi_t = j | Y_t]}
\end{aligned}$$

Finally, the likelihood density of observation y_t is given by:

$$\begin{aligned}
\ell(y_t | Y_{t-1}) &= \sum_{j=1}^m \sum_{i=1}^m f(y_t | \xi_{t-1} = i, \xi_t = j, Y_{t-1}) \Pr [\xi_{t-1} = i, \xi_t = j | Y_t] \\
f(y_t | \xi_{t-1} = i, \xi_t = j, Y_{t-1}) &= (2\pi)^{-N/2} |f_{t|t-1}^{(i,j)}|^{-1/2} \exp \left\{ -\frac{1}{2} e_{t|t-1}^{(i,j)'} f_{t|t-1}^{(i,j)} e_{t|t-1}^{(i,j)} \right\}
\end{aligned}$$

B Solving the MS-DSGE model

In what follows we provide an outline of the solution method used in the paper that should suffice for those readers interested in using the algorithm for applied work. Please refer to Farmer et al. (2010) for further details.

As a first step, define the DSGE state vector S_t as the vector containing all variables of the model. Then, the linearized solution of the model can be rewritten as:

$$\begin{bmatrix} A(\xi_t) \\ a_1(\xi_t) \\ (n-l) \times n \\ a_2(\xi_t) \\ l \times n \end{bmatrix} S_t = \begin{bmatrix} B(\xi_t) \\ b_1(\xi_t) \\ (n-l) \times n \\ b_2(\xi_t) \\ l \times n \end{bmatrix} S_{t-1} + \begin{bmatrix} \Psi(\xi_t) \\ \psi_1(\xi_t) \\ (n-l) \times n \\ \psi_2(\xi_t) \\ l \times n \end{bmatrix} \epsilon_t + \begin{bmatrix} \Pi \\ 0 \\ (n-l) \times l \\ I \\ l \times l \end{bmatrix} \eta_t \quad (16)$$

where ξ_t follows an m -state Markov chain, $\xi_t \in M \equiv \{1, \dots, m\}$, with stationary transition matrix H , n is the number of endogenous variables, k is the number of exogenous shocks, and l is the number of endogenous shocks. Note that the regime changes affecting volatilities are captured by changes in the matrix Ψ . However, if there are not other changes in the model, this has only a multiplicative effect on the initial impact of the *i.i.d.* shocks, but not

on the law of motion of the economy. In this case, standard solution algorithms, such as gensys, can be used.

Farmer et al. (2010) show that:

Theorem 1 FWZ. If $\{x_t, \eta_t\}_{t=1}^{\infty}$ is an MSV solution of the system (16), then:

$$x_t = V_{\xi_t} F_{1, \xi_t} x_{t-1} + V_{\xi_t} G_{1, \xi_t} \varepsilon_t \quad (17)$$

$$\eta_t = - (F_{2, \xi_t} x_{t-1} + G_{2, \xi_t} \varepsilon_t) \quad (18)$$

where the matrix $[A(i)V_i \Pi]$ is invertible, $[A(i)V_i \Pi][F_{1,i} F_{2,i}]' = B(i)$, $[A(i)V_i \Pi][G_{1,i} G_{2,i}]' = \Psi(i)$, and $(\sum_{i=1}^m p_{i,j} F_{2,i}) V_j = 0_{\ell, n-\ell}$, for $1 \leq j \leq m$, where p_{ij} is the transition probability from i to j .

Since $\Pi = [0, I]'$, the matrix $[A(i) V_i]$ is invertible if and only if the upper $(n - \ell) \times (n - \ell)$ block of $A(i)V_i$ is invertible. Without loss of generality, I can assume that $A(i)V_i = [I_{n-\ell}, -X_i]'$. Then, using (18), $F_{2,i} = [0_{\ell, n-\ell} I_{\ell}] [A(i)V_i \Pi]^{-1} B(i) = [X_i I_{\ell}] B(i)$. Therefore, assuming that $A(i)$ is invertible, the problem of finding a MSV solution can be reduced to that of finding the roots of the following polynomial:

$$\sum_{i=1}^m p_{ij} [X_i I_{\ell}] B(i) A(j)^{-1} [I_{n-\ell} - X_j]' = 0_{\ell, n-\ell}$$

In the model considered in this paper, the matrix $A(i)$ is not invertible, and the final steps of the algorithm shown above need to be modified. Please, refer to appendix B of Farmer et al. (2010) for more details.

While the solution method is remarkably fast and efficient for small models, when working with relatively large models such as the one considered in this paper, it becomes important to initialize the algorithm appropriately. Specifically, when looking for a solution for a completely new set of parameters, I found convenient to initialize the solution algorithm using the QZ decomposition of the Γ_0 and Γ_1 that would arise if the two regimes were taken in isolation, i.e. disregarding that agents are in fact aware of regime changes. However, if a solution is available and we are interested in small departures from an old set of parameters, it is generally better to use the old solution as a starting point. These expedients, combined with the estimation strategy described below, proved to be crucial in order to reduce the computational time and make it possible to estimate the model.