Controlling inflation with timid monetary-fiscal regime changes*

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Abstract

Can monetary policy control inflation when both monetary and fiscal policies change over time? When monetary policy is active, a long-run fiscal principle entails flexibility in fiscal policy that preserves determinacy even when deviating from passive fiscal, substantially for brief periods or timidly for prolonged periods. To guarantee a unique equilibrium, monetary and fiscal policies must coordinate not only within but also across regimes, and not simply on being active or passive, but also on their extent. The amplitude of deviations from the active monetary/passive fiscal benchmark determines whether a regime is Ricardian: timid deviations do not imply wealth effects.

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1. Introduction

This work contributes to address the long-standing question regarding the ability of monetary policy to control inflation. Inflation dynamics depend on *current* monetary and fiscal policy interaction and on the expectations about the *future* development of this interaction.

First, inflation dynamics are a joint monetary-fiscal phenomenon. Under conventional views of price level determination, monetary policy is able to control inflation if the rational expectations equilibrium is both unique and Ricardian. A unique equilibrium avoids the presence of multiple stable equilibria that would expose inflation (and output) to endogenous fluctuations. A Ricardian equilibrium ensures the absence of wealth effects from public debt dynamics that would foster spending and affect inflation. Both conditions are satisfied in the New Keynesian framework in which, applying Leeper's (1991) terminology, monetary policy is active and fiscal policy is passive. Monetary policy is said to be active (AM), when the response of the nominal interest rate to inflation is more than one-to-one (otherwise is said to be passive (PM)); fiscal policy is said to be passive (PF) when it controls debt dynamics by adjusting taxes to satisfy the government intertemporal budget constraint (otherwise is said to be active (AF)). In addition to the standard active monetary/passive fiscal (AM/PF) regime, a passive monetary and active fiscal (PM/AF) regime also yields a unique solution. In this case, the response of the nominal interest rate to inflation is less than one-to-one (PM) and fiscal policy determines inflation because the price level must adjust to keep the real value of debt consistent with the government budget constraint (AF). Hence, the so-called fiscal theory of the price level (FTPL) holds, where the absence of Ricardian equivalence produces wealth effects that, in turn, affect inflation.

Second, expectations about future policies are crucial in determining the current equilibrium. The influential contribution by Davig and Leeper (2007b) shows that a passive monetary policy—indeterminate in a static context—could return determinacy if monetary policy is expected to be sufficiently aggressive in the future. The authors conclude that this long-run Taylor principle dramatically expands the determinacy region relative to the constant-parameter setup. Consistent with much of the literature, Davig and Leeper (2007b) do not consider fiscal policy. However, as implied by the FTPL, agents' perceptions of whether government debt will bring about a higher tax burden in the future contribute to determine the inflation outcome. The ability of monetary policy to control inflation today depends on private sector beliefs about whether and how fiscal stress will be resolved in the future. More generally, the expectation of future regimes should be taken into account since *"interest rate policy, tax policy and expenditure policy, both now and as they are expected to evolve in* *the future, jointly determine the price level"* (Sims, 2016).

This paper analyses the type of inflation dynamics implied by differing monetary and fiscal policy mix today and in the future. The aim is to characterise the nature of all the possible different equilibria, and then to draw fresh policy implications. In order to do so, we apply the perturbation method developed by Foerster et al. (2016, henceforth FRWZ) to a simple New Keynesian model with Markov-switching in monetary and fiscal policies. Despite the complexity of the solution algorithm under Markov-switching, we are able to provide some analytical insights into the nature of the solutions regarding both determinacy and implied inflation dynamics. A growing body of literature uses models with recurring regime changes to estimate and study monetary and fiscal policy interactions, as we discuss below. To the best of our knowledge, however, this is the first paper that studies the multiplicity of equilibria resulting from a monetary and fiscal policy interaction in a Markov-switching context using FRWZ's algorithm. The focus of our analysis will be primarily on the case in which one regime is AM/PF, which is the benchmark parametrization in the New Keynesian literature.[2] The theoretical analysis yields a host of new insights that helps rationalise some apparently contradictory results in the literature.

Our first result is to analytically define a *long-run fiscal principle*. The long-run fiscal principle indicates the conditions that a switching fiscal policy needs to satisfy to yield a unique rational expectations equilibrium in the Markov-switching framework, when assuming an active monetary policy. It implies some fiscal policy flexibility that could deviate from passive fiscal policy substantially for brief periods or timidly for prolonged periods. The long-run fiscal principle echoes Davig and Leeper's (2007b) long-run Taylor principle that symmetrically indicates the conditions that a switching monetary policy needs to satisfy to yield a unique rational expectations equilibrium in the Markov-switching framework, when assuming a passive fiscal policy. Our approach, therefore, extends Davig and Leeper's (2007b) intuition to a model in which monetary and fiscal policy interact in determining inflation and economic dynamics.

Our second result shows that, to yield a unique equilibrium, monetary and fiscal authorities should coordinate not only within regimes as suggested by Leeper (1991) but also *across regimes* by choosing the extent of activeness or passiveness. Our analysis leads to a natural generalisation of Leeper (1991) to a Markov-switching context. This generalisation then needs a new taxonomy explained in Section 3. Two cases are noteworthy. First, when one policy is substantially different across regimes, so should the other policy. A substantial deviation in both policies results in an *overall switching* policy mix.

[2] The results, however, can easily be extended to any other regime combination.

Second, when one policy is only timidly different across regimes, so should the other policy. A timid deviation into passive (or active) monetary (or fiscal) policy in one of the regimes returns a policy that is overall active (or passive) monetary (or fiscal) across the two regimes. In this case, we label the policy combination *overall active* (or *passive*). In accordance with this new taxonomy, we show that monetary and fiscal policies need to be balanced across regimes to have a unique equilibrium: either an *overall switching policy mix*, where both policies are substantially switching, or an *overall AM/PF mix*, where policies are allowed some flexibility up to timid deviations.

The third main result regards the nature of the solutions. Our taxonomy delivers a direct link between the concept of balanced policies and the presence of wealth effects or Ricardian dynamics. The literature usually refers to the AM/PF regime as Ricardian and to the PM/AF regime as non-Ricardian only when agents are assumed to be unaware of regime changes. As Bianchi and Melosi (2014) note, in a model with recurrent regime changes, the policy mix is insufficient to establish whether a regime is Ricardian. However, in our setup, the *overall AM/PF mix* allows a limited degree of flexibility for both monetary and fiscal policy and generates a unique Ricardian solution, with no wealth effects in either of the two regimes. Thus, our analysis establishes the conditions such that the unique equilibrium is Ricardian in a model in which agents are aware of recurrent regime changes. In our framework, the fact that agents assign a positive probability of moving towards a PM/AF regime in the future is not a sufficient condition to have wealth effects. Monetary and fiscal policy can timidly deviate from the standard new Keynesian AM/PF regime, and the central bank can still keep inflation under control, because there are no wealth effects arising from timid deviations from passive fiscal policy. In contrast, non-Ricardian dynamics prevail in an *overall switching mix*, that is, where the regime changes are sufficiently large.

Finally, our overall AM/PF regime is consistent with the case of a "timidity trap". Consider an unbacked fiscal expansion under a PM/AF regime, engineered to escape a liquidity trap. If the policy action is too timid, that is, if that PM/AF policy deviates only timidly from the previous AM/PF regime, it would not bring about the wealth effects needed to reflate the economy. To have the desired effects, there should be a clear departure from the previous regime, hence an overall switching mix.

Related literature

Besides Davig and Leeper (2007b) that study determinacy when monetary policy switches, other papers consider regime changes in monetary policy, with fiscal policy constant and passive. Liu et al. (2009) find asymmetric expectation effects after a shift from a dovish monetary regime to a hawkish one. Bianchi (2013) considers postwar data for the U.S. to show with counterfactuals simulations that equilibrium outcomes depend on agents beliefs about alternative dovish or hawkish monetary regimes. Foerster (2016) studies how regime switching in the inflation target affects the determinacy conditions and the probability distributions of macroeconomic variables. Davig and Leeper (2008) make monetary policy regime shifts endogenous.

This paper is related to the literature that studies regime changes in both monetary and fiscal policies. Leeper and Leith (2016) broadly discuss monetary-fiscal policy interactions and their joint effect on inflation dynamics. A bunch of papers estimate Markov switching monetary and fiscal regimes for the U.S. and study the impact of policy shocks using actual and counterfactual impulse response functions (see Davig and Leeper, 2011; Bianchi, 2012; Bianchi and Ilut, 2017; Leeper et al., 2017). In a similar vein, Davig and Leeper (2007a) and Chung et al. (2007) find the fiscal theory of the price level to be always at work when agents believe that fiscal policy may become active in the future. Our methodology does not replicate this finding. As explained in Section 4, this is due to the different solution method and stability concept adopted. Bhattarai et al. (2012) estimate a Markov-switching model using the estimation method by Lubik and Schorfheide (2004) to allow for indeterminacy, and find a PM/PF regime in the pre-Volcker period and an AM/PF regime in the post-Volcker one. Furthermore, Bianchi and Melosi (2014, 2017) study the link between inflation and fiscal imbalances. While we distinguish among timid or substantial departures from a given policy, Bianchi and Melosi (2014) similarly consider short- versus long-lasting deviations. In that respect, Bianchi and Melosi (2014) is the paper most close to ours. However, while our paper studies equilibrium determinacy and the nature of the solution for a range of policy parameters, Bianchi and Melosi (2014) focus just on a given AM/PF regime and a given PM/AF regime. They identify short- and long-lasting deviations between the two regimes by considering different transition probabilities and, in turn, implied durations of the deviations. On the contrary, we identify timid changes with different combinations of policy parameters that ensure determinacy and Ricardian dynamics for given transition probabilities. In Section 4 we obtain the same results of Bianchi and Melosi (2014), when we adapt our more general setting to their case (different transition probabilities towards the same PM/AF regime).

From a technical point of view, the analysis of solution methods for Markov-switching DSGE models is a very active research area. Beside the perturbation approach by FRWZ that we use in this work, other papers develop alternative methods that may differ for the class of equilibrium solutions considered and for the stability criterion in the context of switching parameters (see, among others, Farmer et al., 2009, 2011; Blake and Zampolli, 2011; Maih, 2015; Cho, 2016; Barthelemy and Marx, 2019). As explained in Section 2.2, the perturbation approach by FRWZ uses the notion of mean square stability, proposed by Costa et al. (2005) and Farmer et al. (2009). Other papers (most notably Davig and Leeper, 2007b) use boundedness, which however rules out temporarily explosive paths in one of the regimes. See Farmer et al. (2009) for a discussion on the stability criteria and Barthelemy and Marx (2019) for the determinacy conditions under boundedness.

The paper is structured as follows. Section 2 introduces the model and methodology. Section 3 contains the main results and presents the long-run fiscal principle, our new taxonomy and the implications for policy coordination and for the dynamics of the model. Section 4 shows how our findings differ from those in earlier works on the same topic and how they can be applied to current economic issues. Section 5 concludes.

2. Model and methodology

2.1. The model

We consider a basic New Keynesian model with monetary and fiscal policy rules, as in Bhattarai et al. (2014). The model is well-known and we leave a more complete description in Appendix A.2. In non-linear form, the equations of the model are the following:

$$1 = \beta \mathbb{E}_t \left(\frac{Y_t - G}{Y_{t+1} - G} \frac{R_t}{\Pi_{t+1}} \right), \tag{1}$$

$$\phi_t \left(1 - \alpha \Pi_t^{\theta-1}\right)^{\frac{1}{1-\theta}} = \frac{\mu\theta\left(1-\alpha\right)^{\frac{1}{1-\theta}}}{\theta - 1} Y_t + \alpha\beta\mathbb{E}_t \left[\phi_{t+1}\Pi_{t+1}^{\theta}\left(1 - \alpha\Pi_{t+1}^{\theta-1}\right)^{\frac{1}{1-\theta}}\right], \tag{2}$$

$$\phi_t = \frac{Y_t}{Y_t - G} + \alpha\beta\mathbb{E}_t\left[\Pi_{t+1}^{\theta-1}\phi_{t+1}\right], \tag{3}$$

$$\frac{b_t}{R_t} = \frac{b_{t-1}}{\Pi_t} + G - \tau_t, \tag{4}$$

$$\tau_t = \tau \left(\frac{b_{t-1}}{b}\right)^{\gamma_{\tau,t}} e^{u_{\tau,t}}, \tag{5}$$

$$R_t = R\left(\Pi_t\right)^{\gamma_{\pi,t}} e^{u_{m,t}}. \tag{6}$$

Equation (1) is a standard Euler equation for consumption, where Y_t is output, R_t the nominal interest rate, Π_t the gross inflation rate and G government spending, which is assumed to be exogenous and constant. Equations (2) and (3) describe the evolution of inflation in the non-linear model. ϕ_t is an auxiliary variable (equal to the present discounted value of expected future marginal revenues) that allows us to write the model recursively. Equation (4) is the government's flow budget constraint, where $b_t = B_t/P_t$ is real government debt. We follow Leeper (1991) in using lump-sum taxes (τ_t), which are set according to the fiscal rule (5): taxes react to the deviation of lagged real debt from its steady-state level (b) according to the parameter $\gamma_{\tau,t}$. Equation (6) describes monetary policy. It is a simple Taylor rule whereby the central bank reacts to current inflation according to the parameter $\gamma_{\pi,t}$. A variable without the time index (i.e., τ, b and R) indicates the value at the steady state. β is the intertemporal discount factor; θ is the Dixit-Stiglitz elasticity of substitution between goods; and α is the Calvo probability that a firm is unable to optimise its price.

The key parameters of our analysis are $\gamma_{\pi,t}$ and $\gamma_{\tau,t}$, which describe the time-varying stance of monetary and fiscal policy, respectively. We assume that these parameters follow an underlying two-state Markov process and are equal to ($\gamma_{\pi,i}$, $\gamma_{\tau,i}$) when the economy is in regime i, for $i = 1, 2$. The transition probabilities of going from regime i to regime j are denoted by p_{ij}. Thus, p_{ii} is the probability of remaining in regime i, and $p_{ij} = 1 - p_{ii}$.

2.2. Solution method

As our model includes fiscal policy, we need to account for the dynamics of public debt, which is a state variable. We thus employ the perturbation method developed by FRWZ, the logic of which is analogous to an undetermined coefficient method applied to a Markov-switching context. It allows us to solve for all the *minimal state variable (MSV) solutions* of a Markov-switching model in the presence of predetermined variables.[3] Following FRWZ, our model can be written as follows:

$$\mathbb{E}_t \boldsymbol{f} \left(\boldsymbol{y}_{t+1}, \boldsymbol{y}_t, b_t, b_{t-1}, \boldsymbol{\varepsilon}_{t+1}, \boldsymbol{\varepsilon}_t, \boldsymbol{\theta}_{t+1}, \boldsymbol{\theta}_t \right) = \mathbf{0}, \tag{7}$$

where b_t is the only predetermined variable, while the remaining non-predetermined variables are stacked in vector $\boldsymbol{y}_t' \equiv [Y_t, \Pi_t, \phi_t]$. The exogenous shocks appear in vector $\boldsymbol{\varepsilon}_t' \equiv [u_{m,t}, u_{\tau,t}]$, and $\boldsymbol{\theta}_t' \equiv [\gamma_{\pi,t}, \gamma_{\tau,t}]$ is the vector of Markov-switching parameters. The first-order Taylor expansions of the recursive solutions are

$$b_t \approx b + h_i(b_{t-1} - b) + \boldsymbol{h}_{i,\varepsilon}\boldsymbol{\varepsilon}_t + h_{i,\chi}\chi, \tag{8}$$

$$\boldsymbol{y}_t \approx \boldsymbol{y} + \boldsymbol{g}_{i,b}(b_{t-1} - b) + \boldsymbol{g}_{i,\varepsilon}\boldsymbol{\varepsilon}_t + \boldsymbol{g}_{i,\chi}\chi, \tag{9}$$

[3] Hence, by using this method, we consider only MSV solutions. While some other non-MSV solutions may still exist, the class of MSV solutions is usually the one employed in the estimation of DSGE models.

for $i = 1, 2$, where χ is the perturbation parameter. Note that the slope coefficients of the solutions are regime-dependent, while the steady state is not. The coefficients h_1 and h_2 govern the stability properties of the solution and are therefore the main focus in the analysis of determinacy. FRWZ show that h_i and $\boldsymbol{g}_{i,b}$ can be jointly found after solving a system of quadratic equations. As this system cannot be solved using traditional approaches such as the generalised Schur decomposition, we follow FRWZ and adopt the Groebner basis algorithm to find all existing MSV solutions.

Once all the solutions belonging to the MSV class of equilibria have been found, a stability criterion needs to be imposed to select the stable ones. We use the concept of *mean square stability* (MSS) as advocated by Farmer et al. (2009). The MSS condition constrains the values of the autoregressive roots in the state variable policy function in the two regimes. In Appendix A.3, we show that the necessary and sufficient conditions for MSS are

$$(p_{11} + p_{22} - 1)\, h_1^2 h_2^2 < 1, \tag{10}$$

$$p_{11} h_1^2 \left(1 - h_2^2\right) + p_{22} h_2^2 \left(1 - h_1^2\right) + h_1^2 h_2^2 < 1, \tag{11}$$

for $p_{11} + p_{22} > 1$. Therefore, any given parameter configuration could lead to the following three cases: (i) determinacy, when a unique stable MSV solution exists; (ii) indeterminacy, when multiple stable MSV solutions exist; or (iii) explosiveness, when no stable MSV solutions exist. In what follows, we seek to explore the parameter space to identify the regions corresponding to these three cases.[4]

2.3. Determinacy under fixed coefficients: Leeper (1991)

It is useful here to recall the necessary and sufficient conditions for determinacy of the rational expectations equilibrium (REE) in a fixed-coefficient model. Assume thus for the moment that both $\gamma_{\pi,t}$ and $\gamma_{\tau,t}$ are constant over time and not subject to regime changes, as in Leeper (1991). The log-linearised model is a trivariate dynamic system in the two jump variables $\hat{Y}_t$ and $\hat{\Pi}_t$ and the predetermined variable $\hat{b}_t$

$$\frac{1}{\bar{c}}\hat{Y}_t = \frac{1}{\bar{c}}\mathbb{E}_t\hat{Y}_{t+1} - \left(\hat{R}_t - \mathbb{E}_t\hat{\Pi}_{t+1}\right), \tag{12}$$

$$\hat{\Pi}_t = \frac{\lambda}{\bar{c}}\hat{Y}_t + \beta\mathbb{E}_t\hat{\Pi}_{t+1}, \tag{13}$$

[4]Note that the term indeterminacy is used here in a different way from that used in the sunspot literature. Since we only consider MSV solutions, we do not consider sunspots in our model. Indeterminacy here means that there is more than one (generally a discrete number of) stable, and thus admissible, MSV solutions.

$$\hat{R}_t = \gamma_\pi \hat{\Pi}_t + u_{m,t}, \tag{14}$$

$$\hat{b}_t = \frac{1}{\beta}\left(1 - \frac{\tau}{b}\gamma_\tau\right)\hat{b}_{t-1} - \frac{1}{\beta}\hat{\Pi}_t + \hat{R}_t - \frac{1}{\beta}\frac{\tau}{b}u_{\tau,t}, \tag{15}$$

where $\bar{c}$ is the steady-state consumption-to-GDP ratio, $\lambda \equiv (1-\alpha)(1-\alpha\beta)/\alpha$ determines the slope of the Phillips curve, and hatted variables indicate log-deviations from steady-state values. Using Leeper's (1991) well-known taxonomy, fiscal policy is said to be *passive* if the fiscal rule guarantees debt stabilisation in (15), that is, if the following holds:

$$\left|\frac{1}{\beta}\left(1 - \frac{\tau}{b}\gamma_\tau\right)\right| < 1. \tag{16}$$

In the case of passive fiscal policy, the following conditions have to hold to yield determinacy:

$$\gamma_\pi > 1 \quad \text{and} \quad \gamma_\pi > \frac{\beta - 1}{\lambda}. \tag{17}$$

The first condition is the Taylor principle, and it implies the second, which then becomes redundant. According to Leeper's (1991) taxonomy, monetary policy is labelled *active* if it satisfies the Taylor principle; otherwise, it is labelled *passive*. Hence, the famous result in Leeper (1991) follows: when fiscal policy is passive, monetary policy needs to be active (i.e., $\gamma_\pi > 1$) to yield determinacy.

Conversely, in the case of active fiscal policy (i.e., when (16) does not hold), monetary policy should be passive to guarantee determinacy: $\gamma_\pi < 1$. In this case, a change in lump-sum taxation has real effects, and the so-called fiscal theory of the price level holds.[5] The literature often refers to the AM/PF regime by the term Ricardian, while the term non-Ricardian is used for the PM/AF regime. Only in the former case there are no wealth effects, and thus no effects on output and inflation, from a change in lump-sum taxes for a given stream of expenditures, as prescribed by Ricardian equivalence. However, this straightforward one-to-one mapping between the policy mix and the Ricardian terminology is possible only if there are no regime changes (or agents are not aware of them). In what follows, we will define the conditions for this mapping in a Markov-switching context. We will label Ricardian dynamics the cases in which changes in lump-sum taxes (and hence the debt level) have no effects on output and inflation. Thus, a Ricardian solution will feature no wealth effects in both regimes after a change in the path of lump-sum taxes.

In summary, in a fixed-coefficient model, as in Leeper (1991), the determinacy region is defined by

[5] See Bhattarai et al. (2014) for a thorough analysis of the dynamics implied by such a parameter configuration.

the following conditions:

1. Active monetary/passive fiscal (AM/PF): $\gamma_\pi > 1$ and $(1-\beta)\frac{b}{\tau} < \gamma_\tau < (1+\beta)\frac{b}{\tau}$;

2. Passive monetary/active fiscal (PM/AF): $\gamma_\pi < 1$ and either $\gamma_\tau < (1-\beta)\frac{b}{\tau}$ or $\gamma_\tau > (1+\beta)\frac{b}{\tau}$.

The REE is indeterminate under the PM/PF configuration and explosive under the AM/AF configuration.

2.4. Determinacy under regime switching

Applying the FRWZ method, Appendix A.3 shows that solutions to the model (1)-(6) need to satisfy the following system of equations for the Markov-switching case:

$$\begin{aligned} 0 = {} & g_{\pi,1}\left[1+\lambda\gamma_{\pi,1} - p_{11}h_1(1+\beta+\lambda) + p_{11}^2\beta h_1^2\right] + (1-p_{11})(1-p_{22})\beta h_1 h_2 g_{\pi,1} \\ & + (1-p_{11})h_1 g_{\pi,2}\left[p_{11}\beta h_1 + p_{22}\beta h_2 - (1+\beta+\lambda)\right], \end{aligned} \tag{18}$$

$$\begin{aligned} 0 = {} & g_{\pi,2}\left[1+\lambda\gamma_{\pi,2} - p_{22}h_2(1+\beta+\lambda) + p_{22}^2\beta h_2^2\right] + (1-p_{11})(1-p_{22})\beta h_1 h_2 g_{\pi,2} \\ & + (1-p_{22})h_2 g_{\pi,1}\left[p_{11}\beta h_1 + p_{22}\beta h_2 - (1+\beta+\lambda)\right], \end{aligned} \tag{19}$$

$$g_{\pi,1} = \frac{\frac{1}{\beta}\left(1-\frac{\tau}{b}\gamma_{\tau,1}\right) - h_1}{b\left(\frac{1}{\beta}-\gamma_{\pi,1}\right)}, \tag{20}$$

$$g_{\pi,2} = \frac{\frac{1}{\beta}\left(1-\frac{\tau}{b}\gamma_{\tau,2}\right) - h_2}{b\left(\frac{1}{\beta}-\gamma_{\pi,2}\right)}, \tag{21}$$

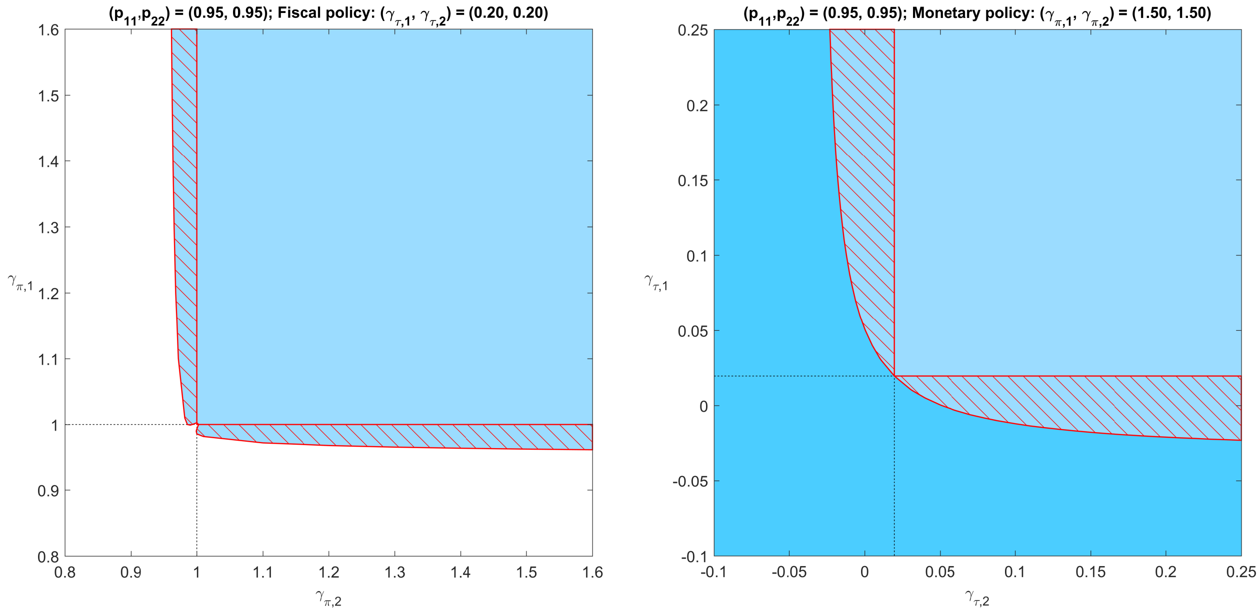
where $p_{11}, p_{22} \in (0,1)$ and the 4 unknowns are h_1, h_2, $g_{\pi,1}$ and $g_{\pi,2}$. Debt, b_t, is the state variable of the system; h_i is the response of debt to its lag in regime i in (8), and $g_{\pi,i}$ is the response of inflation to the lagged debt in regime i (i.e., the element of $g_{i,b}$ that corresponds to inflation in (9)). Determinacy obtains when a single pair (h_1, h_2) satisfies the MSS conditions (10)-(11). As explained above, a solution is Ricardian if $g_{\pi,i} = 0$, for $i = 1, 2$, because inflation dynamics do not depend on the debt level, while they would in the FTPL case (see Bhattarai et al., 2014).

3. Results

3.1. The long-run Taylor principle and the monetary policy frontier

Davig and Leeper's (2007b) long-run Taylor principle indicates the conditions that a switching monetary policy needs to satisfy under the two regimes to yield a unique REE in the Markov-switching framework, when assuming a passive fiscal policy. Figure 1a displays what we label the *monetary policy frontier* (henceforth MPF) because it delimits the combinations of monetary policy rule coefficients ($\gamma_{\pi,1}$ and $\gamma_{\pi,2}$) in the two regimes that deliver determinate equilibria for given fiscal rule coefficients. The combination of monetary policies between the two regimes above the MPF in the figure delivers a unique REE. In contrast, the others monetary policy mixes admit more than one stable solution. The MPF in Figure 1a assumes an always passive fiscal policy (i.e., $\gamma_{\tau,1} = \gamma_{\tau,2} = 0.2$), and thus, it reproduces, in our framework, the long-run Taylor principle: determinacy can obtain even if monetary policy is deviating from the Taylor principle in one of the two regimes. However, the monetary policy combination above the MPF admits only timid deviations into passive monetary policy. We define a "timid" deviation from active into passive monetary policy one that still allows the monetary policy mix to be above the MPF and hence to return a determinate equilibrium. These timid deviations are the ones highlighted by the hatched area in the figure. By substantial deviation from active monetary policy, we instead indicate a stronger deviation of monetary policy that brings the monetary policy mix beyond the MPF, which would render the equilibrium indeterminate. As we will show in Section 4, it is important to stress that our definition of timid/substantial deviation is also conditional on the values of transition probabilities. As in Davig and Leeper (2007b), asymmetric mean duration would expand the determinacy region in favour of the more transient regime, such that these deviations could be timid for prolonged periods or substantial for brief periods. The intuition is straightforward: in a regime-switching context, the possibility of switching to an active policy in one regime anchors expectations and allows some flexibility in monetary policy to relax the Taylor principle in the other regime. The degree of flexibility, however, is limited by the overall combination of monetary policies across the two regimes. Uniqueness is guaranteed if monetary policy is "overall" active across the two regimes, that is, if these deviations are timid such that the monetary policy mix is above the MPF. In this case we name the monetary policy mix *overall AM*.[6] Finally, it is worth emphasising that the unique solutions inside the MPF deliver standard New-Keynesian dynamics, in the sense that they are Ricardian solutions, as defined above.

[6]Unfortunately, given the complexity of the system, a meaningful analytic expression for the MPF is not possible. Nonetheless, we will later provide revealing analytic insights for the case of an absorbing regime.



(a) The monetary policy frontier

(b) The fiscal policy frontier

Figure 1: The monetary and fiscal policy frontiers.

Notes: Light blue: unique solution; white: indeterminacy; dark blue: explosiveness. The dashed lines correspond to the Leeper's (1991) threshold between active and passive monetary and fiscal policy in a constant coefficients framework. The hatched areas in (a) and (b) highlight the timid deviation from active monetary policy and passive fiscal policy, respectively.

3.2. Allowing flexibility in fiscal policy: The long-run fiscal principle and the fiscal policy frontier

Our setup allows us to map the insights of the MPF into a specular graph for fiscal policy. That is, we can perform a similar analysis, defining the conditions that fiscal policy needs to satisfy to yield a unique REE, for a given combination of monetary policies. Assume that monetary policy is always active ($\gamma_{\pi,1} = \gamma_{\pi,2} = 1.5$). This will be the symmetric case with respect to Davig and Leeper (2007b), who implicitly consider passive fiscal policy in both regimes. Figure 1b displays what we label the *fiscal policy frontier* (henceforth FPF) because it shows the combination of fiscal policy rule coefficients ($\gamma_{\tau,1}$ and $\gamma_{\tau,2}$) under the two regimes that delivers determinate equilibria for the given monetary rule coefficients. As the figure shows, we have determinacy above the FPF. The logic and intuition is the same as for the case of monetary policy. Determinacy can obtain even if fiscal policy is deviating timidly from a passive policy in one of the two regimes, as highlighted by the hatched area in Figure 1b. The possibility of switching to a passive policy in one regime anchors expectations and it allows some flexibility for fiscal policy to be active in the other regime. Uniqueness is guaranteed if fiscal policy is "overall" passive across the two regimes, that is, if these deviations are timid such that the fiscal policy combination is above the FPF. In this case, we name the fiscal policy mix *overall PF*.

Given the conditions (18)-(21), the following proposition analytically defines the FPF.

Proposition 1. ***The Fiscal Policy Frontier.*** *For any policy parameter combination, there always exists a particular solution such that in each regime* $h_i = \frac{1}{\beta}\left(1 - \frac{\tau}{b}\gamma_{\tau,i}\right) \equiv \bar{h}_i(\gamma_{\tau,i})$ *and* $g_{\pi,i} = 0$*, for* $i = 1, 2$*. This solution thus depends only on* $\gamma_{\tau,i}$ *for* $i = 1, 2$*. Then:*

(i) For this solution to be MSS, it must be true that h_1 *and* h_2 *satisfy*

(22)
$$p_{11}\left[\bar{h}_1(\gamma_{\tau,1})\right]^2\left\{1 - \left[\bar{h}_2(\gamma_{\tau,2})\right]^2\right\} + p_{22}\left[\bar{h}_2(\gamma_{\tau,2})\right]^2\left\{1 - \left[\bar{h}_1(\gamma_{\tau,1})\right]^2\right\} + \left[\bar{h}_1(\gamma_{\tau,1})\bar{h}_2(\gamma_{\tau,2})\right]^2 < 1,$$

which defines the FPF in the space $(\gamma_{\tau,1}, \gamma_{\tau,2})$*.*

(ii) The fiscal policy frontier is independent of the monetary policy coefficients.

(iii) This solution yields no wealth effects in both regimes because $g_{\pi,i} = 0$ *for* $i = 1, 2$*, and thus, it is a Ricardian solution.*

Proposition 1 establishes some important results. First, we can characterise analytically one particular solution. For any fiscal policy mix, i.e., $\gamma_{\tau,1}$ and $\gamma_{\tau,2}$, there always exist values $\bar{h}_1(\gamma_{\tau,1})$ and $\bar{h}_2(\gamma_{\tau,2})$ such that $g_{\pi,1} = g_{\pi,1} = 0$ in (20) and (21). Hence, these values $\bar{h}_1(\gamma_{\tau,1})$ and $\bar{h}_2(\gamma_{\tau,2})$ define a solution because they also satisfy (18) and (19). Second, this solution is MSS if it satisfies (22), which defines the FPF in Figure 1b. Third, this is the Ricardian solution: since $g_{\pi,1} = g_{\pi,2} = 0$, inflation and output do not react to a change in the debt level, and thus this solution yields no wealth effects under either regime. Finally, note that both the solution and its stability condition do not depend on the monetary policy coefficients. However, the monetary policy coefficients determine whether other possible MSS solutions exist (see Section 3.3 below).

Corollary 1. ***The long-run fiscal principle.*** *Assume that monetary policy is always active; then, (22) defines the long-run fiscal principle, that is, if the fiscal policy mix* $(\gamma_{\tau,1}, \gamma_{\tau,2})$ *satisfies (22), there is a unique Ricardian solution.*

The corollary fixes two important results that stem from our analysis. Consider the fiscal stance underlying the long-run Taylor principle in Davig and Leeper (2007b) and Figure 1a. It entails an always-passive fiscal policy: the central bank can stabilise the economy by following the Taylor principle or deviating from it, substantially for brief periods or timidly for longer periods, provided that it is backed by a government that implements the fiscal adjustments necessary to stabilise debt.

Symmetrically, Figure 1b shows what we can analogously name the *long-run fiscal principle*, given by equation (22): fiscal policy can also deviate substantially from passive behaviour for brief periods or timidly for longer periods and still return determinacy, provided that monetary policy is always active.[7]

Second, Proposition 1 proves that the solution is Ricardian (i.e., $g_{\pi,i} = 0$ for $i = 1, 2$), and Figure 1b shows that it is unique because no other MSS solutions exist, given that monetary policy is always active. Figure 1 displays the regions of the determinacy space where solutions are Ricardian and establishes similarity between flexibility in monetary policy and that in fiscal policy, as long as one of the two policies is always AM or PF. This tells us that if one of the two policies is always 'well-behaved', the other can deviate timidly without changing the qualitative nature of the dynamics, which remain Ricardian in both regimes. In this case, the fiscal rule guarantees debt stabilisation, and monetary policy controls inflation in both regimes. Inflation is monetary determined and the standard New Keynesian (AM/PF) solution applies in both regimes.

However, our framework admits non-Ricardian solutions when *both regimes admit a stable solution with wealth effects*, i.e., such that $g_{\pi,i} \neq 0$. These solutions would imply spillovers across regimes and FTPL dynamics, as there is no fiscal backing for the government budget constraint. The price level has to move to stabilise debt: inflation is fiscally determined, and monetary policy would not be able to fully control inflation. Depending on parameter configurations, these two types of solutions could co-exist, thus leading to multiple stable solutions, as in the white region in Figure 1a. What then are the limits to flexibility to guarantee a unique determinate equilibrium? What are the conditions for wealth effects and FTPL dynamics to arise?

3.3. The extent of flexibility

Thus far, in defining the FPF, we assumed that monetary policy was always active in both regimes. However, how should fiscal policy behave to yield determinacy when monetary policy switches from active to passive in one regime? To answer this question, we need to distinguish two cases, according to whether $\gamma_{\pi,2}$ deviates from the Taylor principle to a lesser (case 1) or greater (case 2) extent. Moreover, we need to generalise the Leeper's (1991) taxonomy to the Markov switching case. The resulting new taxonomy is necessarily more complex and Table 1 presents a guide to the different definitions used in the text.

[7] See Section 4 for an example of determinacy after a substantial variation for a brief period.

Table 1. A new taxonomy

Panel A

Assume regime 1 is AM/PF according to Leeper (1991), then regime 2 can exhibit:

Timid deviation from AM	Monetary policy is passive (according to Leeper, 1991), but mildly so, such that the Taylor rule coefficient is still inside the monetary policy frontier, i.e., hatched area in Figure 1a.
Substantial deviation from AM	Monetary policy is definitely passive, such that the Taylor rule coefficient is outside the monetary policy frontier.
Timid deviation from PF	Fiscal policy is active (according to Leeper, 1991), but mildly so, such that the fiscal rule coefficient is still inside the fiscal policy frontier, i.e., hatched area in Figure 1b.
Substantial deviation from PF	Fiscal policy is definitely active, such that the fiscal rule coefficient is outside the fiscal policy frontier.

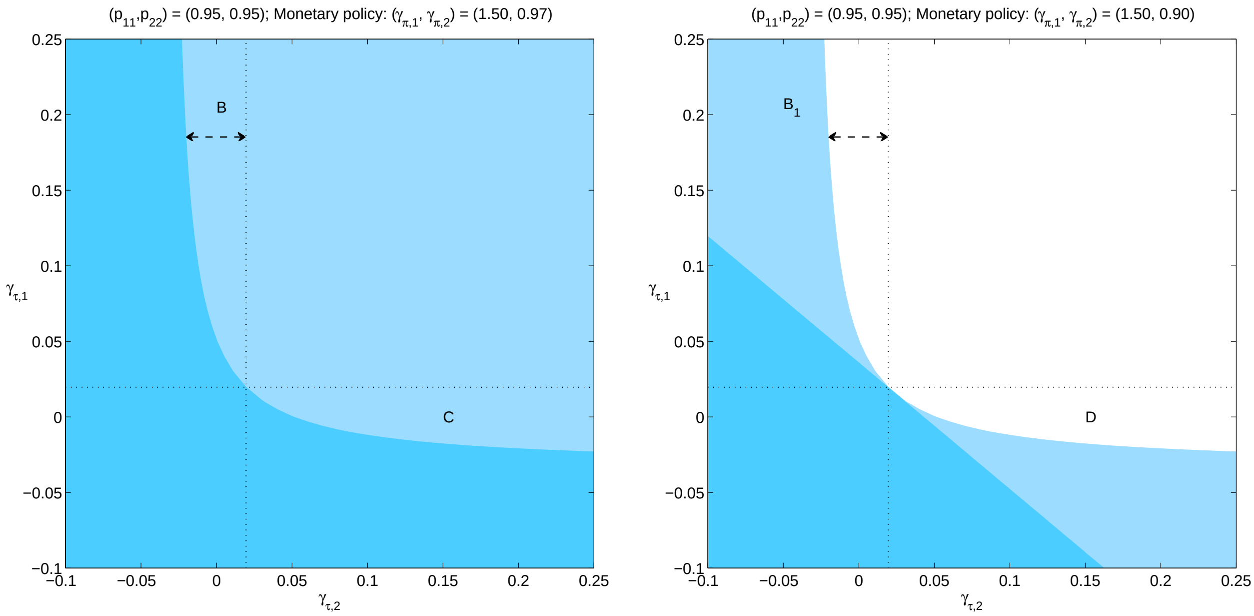
Given above, define the monetary and the fiscal policy stance across the 2 regimes:

Overall AM	AM in one regime accompanied by AM or a timid deviation from AM in the other regime.
Switching monetary policy	AM in one regime accompanied by substantial deviation from AM in the other regime.
Overall PF	PF in one regime accompanied by PF or a timid deviation from PF in the other regime.
Switching fiscal policy	PF in one regime accompanied by substantial deviation from PF in the other regime.

Panel B

Given above, define the type of monetary and fiscal policy mix across the 2 regimes:

	Overall PF	Switching fiscal policy
Overall AM	**Overall AM/PF mix** balanced mix, determinate Ricardian, no wealth effects	Unbalanced mix, indeterminate
Switching monetary policy	Unbalanced mix, indeterminate	**Overall switching mix** balanced mix, determinate non-Ricardian, wealth effects



(a) Timid deviations

(b) Substantial deviations

Figure 2: The fiscal policy frontier for different monetary regimes.
Notes: Light blue: unique solution; white: indeterminacy; dark blue: explosiveness.

Case 1: A timid $\gamma_{\pi,2}$ deviation. Assume that monetary policy is active under the first regime and deviates only timidly under the second regime ($\gamma_{\pi,1} = 1.5$, $\gamma_{\pi,2} = 0.97$). In terms of Figure 1a, the long-run Taylor principle is satisfied: the monetary policy mix is above the MPF and *overall active*. Then, Figure 2a shows that the FPF is the same as in Figure 1a above: again determinacy is preserved if fiscal policy deviates only timidly into the AF territory in one of the regimes. Both monetary and fiscal policy could admit some flexibility as long as the deviations from the AM and PF regime are *both* timid, such that we have an *overall AM* combined with an *overall PF*, which returns what we name an *overall AM/PF mix*. Both the long-run Taylor principle and the long-run fiscal principle are satisfied. The deviations of both monetary and fiscal policy are so timid that only the Ricardian solution exists.

Our analysis suggests that the long-run Taylor principle holds, as long as the long-run fiscal principle does. They are intimately intertwined. Consider a policy mix that lies above the FPF with passive fiscal policy under regime 1 and a timidly active fiscal policy under regime 2. The corresponding MPF for this overall PF is very similar to that in Figure 1a.[8] In other words, as the FPF is unaffected as long as the monetary policy stance is overall active, i.e., the long-run Taylor principle is satisfied, the MPF is also largely unaffected as long as the fiscal stance is overall passive, i.e., as long as the

[8]For the sake of brevity, we omit that figure, which is available from the authors upon request.

long-run fiscal principle is satisfied. It follows that the long-run Taylor principle ensures determinacy not only when fiscal policy is always passive, as Davig and Leeper (2007b) maintain, but also when it deviates timidly into active fiscal territory for some time, provided that the long-run fiscal principle is satisfied.

Case 2: A substantial $\gamma_{\pi,2}$ deviation. Now assume a *substantial* deviation of monetary policy into the passive territory (e.g., $\gamma_{\pi,2} = 0.9$, see Figure 2b). The monetary policy stance is definitely switching from active to passive, and thus, the long-run Taylor principle is not satisfied and the monetary policy mix cannot be defined *overall AM*. Instead, we label this mix as the *switching monetary policy*. If the fiscal policy mix remains *overall PF*, there would be indeterminacy. The long-run Taylor principle is not satisfied, and, in turn, both an always-passive fiscal policy mix (see Figure 1a) or a timid deviation (see Figure 2b) from passive fiscal policy return indeterminacy. Determinacy generally requires fiscal policy to deviate *substantially* from passive behaviour, too. The fiscal policy mix needs to be below the FPF to yield determinacy, that is, the long-run fiscal principle should not be satisfied. Fiscal policy should deviate from *overall PF*, definitely switching from passive to active. We name such a fiscal policy mix the *switching fiscal policy*. Note that this is merely a sufficient but not a necessary condition because switching fiscal policies could also return instability, as visible in Figure 2b.

To gain further insight into this result, note that in Figure 2b a new condition appears, represented as a straight line in the space $(\gamma_{\tau,1}, \gamma_{\tau,2})$. This line indicates the threshold for the existence of an MSS non-Ricardian solution: above the line, the policy parameters (and the probabilities of switching) are such that at least one non-Ricardian MSS solution exists, while below the line no stable solution exists. Moreover, we also know from Proposition 1 that a Ricardian MSS solution always exists above the FPF. In Figure 2b, the threshold line is below the FPF.[9] Thus, for all the fiscal combinations above the FPF, there are at least two stable solutions (one Ricardian and at least one non-Ricardian) which are therefore indeterminate. Below the line, no stable solution exists. Between the FPF and the line, we find determinacy.[10] There is a unique non-Ricardian solution: Ricardian equivalence does not hold

[9] To be clear, the line lies below the FPF and is not tangent to the FPF, as it might appear from the figure.

[10] Appendix A.6 contains the full analytical characterisation of the threshold condition that defines the line in the absorbing case. Such an expression is not available in any meaningful sense for the general case. In general, the slope and position of the line depend on the monetary policy coefficients $\gamma_{\pi,i}$ and the switching probabilities p_{ii}. For the parameter combinations in Figure 2b, the line lies below the FPF. For larger switches into PM (i.e., lower $\gamma_{\pi,2}$) or different regime persistences, the line could also intersect the FPF. However, our general message remains valid because there will always be a policy combination that yields a unique determinate solution. This again simply reflects the fact that the monetary frontier generally depends on the fiscal policy mix in the two regimes.

and the dynamics would imply wealth effects in both regimes, meaning that changes in the debt level affect output and inflation. Hence, in the case of switching policies, the unique equilibrium delivers very different dynamics with respect to those defined by the *overall AM/PF mix.*

3.3.1. An analytical definition of the extent of flexibility: timid vs substantial deviations in the absorbing AM/PF case

We now refer to the case in which regime 1 is AM/PF and absorbing, and hence, $p_{11} = 1$. This simplification allows us to derive analytical results on determinacy and, in turn, to develop intuition concerning the numerical results in the general case. We refer the interested reader to Appendix A.6 for the full derivations of the analytical results for the absorbing case. If $p_{11} = 1$, equations (18) and (20) reduce to

$$0 = \frac{\frac{1}{\beta}\left(1 - \frac{\tau}{b}\gamma_{\tau,1}\right) - h_1}{b\left(\frac{1}{\beta} - \gamma_{\pi,1}\right)}\left[1 + \lambda\gamma_{\pi,1} - h_1\left(1 + \beta + \lambda\right) + \beta h_1^2\right] \tag{23}$$

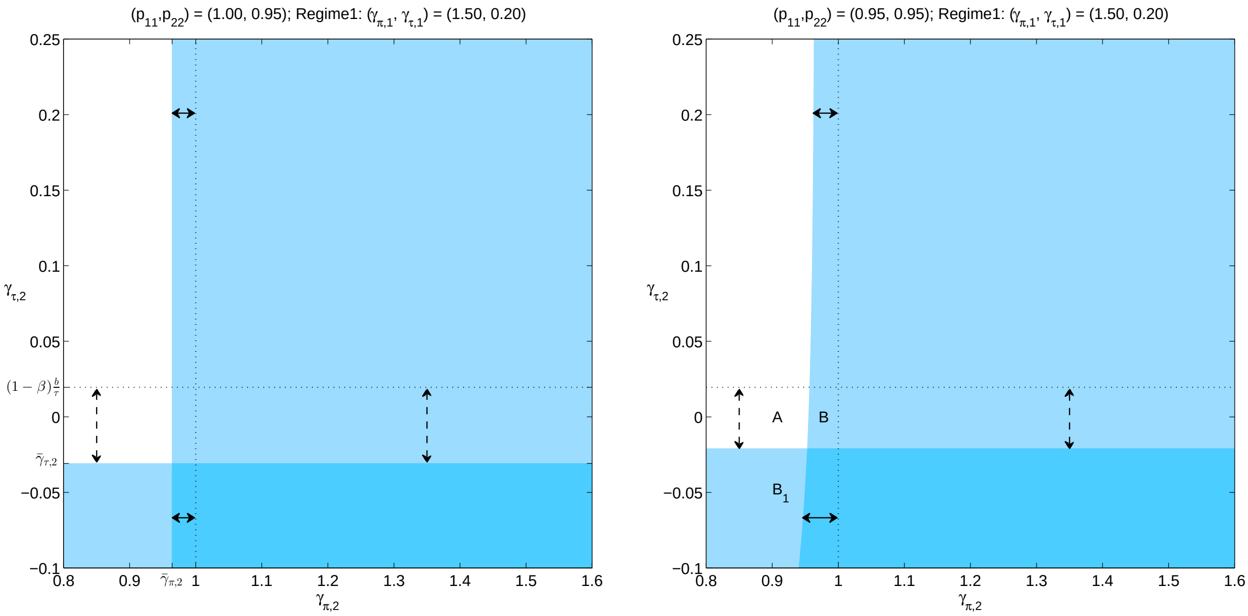
and the conditions for MSS, i.e., (10) and (11), simplify to $|h_1| < 1$ and $|h_2| < \frac{1}{\sqrt{p_{22}}}$.

If the economy is already in the absorbing regime 1, the conditions for determinacy are clearly the same as under fixed coefficients. Hence, if fiscal policy is passive, condition (16) must hold ($\frac{b}{\tau}(1-\beta) < \gamma_{\tau,1} < \frac{b}{\tau}(1+\beta)$),[11] and monetary policy must be active ($\gamma_{\pi,1} > 1$). Conversely, the Markov-switching nature of the economy obviously affects the stability condition in the non-absorbing regime. With respect to the fixed-coefficient case, the stability condition (i.e., $|h_2| < \frac{1}{\sqrt{p_{22}}}$) is less binding, the lower the probability of remaining in the second state is. Figure 3a depicts the combinations of the monetary ($\gamma_{\pi,2}$) and the fiscal ($\gamma_{\tau,2}$) coefficients for the second regime (setting $p_{22} = 0.95$) that return determinacy of the Markov-switching equilibrium given an absorbing AM/PF regime 1 ($\gamma_{\pi,1} = 1.5$, $\gamma_{\tau,1} = 0.2$). Notably, there are two regions in the ($\gamma_{\pi,2}, \gamma_{\tau,2}$) space that return determinacy: an upper-right zone and a lower-left zone.

First, let us analyse the upper-right zone. In this case, there is MSS if the following conditions concerning regime 2 hold:

$$\gamma_{\tau,2} \in \left(\bar{\gamma}_{\tau,2}, \frac{b}{\tau}\left(1 + \frac{\beta}{\sqrt{p_{22}}}\right)\right), \tag{24}$$

[11] Our calibration yields $0.019 < \gamma_{\tau,1} < 3.892$. The calibration is described in Table A1 in appendix. We do not discuss it in the main text because it is very standard, and our model is too stylised to make the case for a quantitative analysis. However, the logic of our analyses and results does not depend on the particular calibration chosen.



(a) Absorbing case

(b) Non-absorbing case

Figure 3: Determinacy regions when regime 1 is AM/PF.

Notes: Light blue: unique solution; white: indeterminacy; dark blue: explosiveness. The solid lines with arrows indicate a timid deviation from active monetary policy; the dashed lines with arrows indicate a timid deviation from passive fiscal policy.

(25) $$\gamma_{\pi,2} > \bar{\gamma}_{\pi,2},$$

where $\bar{\gamma}_{\tau,2} \equiv \frac{b}{\tau}\left(1 - \frac{\beta}{\sqrt{p_{22}}}\right)$, and $\bar{\gamma}_{\pi,2} \equiv \sqrt{p_{22}} - \frac{\left(1-\beta\sqrt{p_{22}}\right)\left(1-\sqrt{p_{22}}\right)}{\lambda}$. Determinacy clearly emerges when the second regime is AM/PF, too. However, the threshold values $\bar{\gamma}_{\tau,2}$ and $\bar{\gamma}_{\pi,2}$ imply that both intervals for $\gamma_{\tau,2}$ and $\gamma_{\pi,2}$ widen, relative to the fixed-coefficients result: there is determinacy even if the second regime deviates from Leeper's (1991) definition of the AM/PF mix. Careful consideration of the above conditions reveals that $\bar{\gamma}_{\tau,2}$ is negative, if $\sqrt{p_{22}} < \beta$, while $\bar{\gamma}_{\pi,2}$ is lower than one because $\sqrt{p_{22}} < 1$. In other words, to have determinacy, fiscal and monetary policy in the second regime are not constrained to always be passive and active, respectively. Rather, they can be "timidly" active and passive, respectively. This effect is more pronounced the lower p_{22} is. The timid changes for fiscal and for monetary policy are given by the following intervals (visualised by the dotted and solid arrows in Figure 3a):

(26) $$\bar{\gamma}_{\tau,2} < \gamma_{\tau,2} < \frac{b}{\tau}\left(1 - \beta\right),$$

(27) $$\bar{\gamma}_{\pi,2} < \gamma_{\pi,2} < 1.$$

Consider now what happens in the lower-left zone. There is global MSS if the following holds:

$$\gamma_{\tau,2} < \bar{\gamma}_{\tau,2} \text{ and } \gamma_{\tau,2} > \frac{b}{\tau}\left(1 + \frac{\beta}{\sqrt{p_{22}}}\right), \tag{28}$$

$$\gamma_{\pi,2} < \bar{\gamma}_{\pi,2}. \tag{29}$$

In this case, to have determinacy, fiscal and monetary policies in the second regime are constrained to always be "more than" active and "more than" passive, respectively, relative to Leeper's (1991) conditions. Hence, *both* monetary policy *and* fiscal policy in regime 2 must deviate "substantially" from the other AM/PF regime.

The absorbing case usefully provides easy intuition about the results in the previous sections of the paper, regarding flexibility, its limit and the link between the determinacy analysis and the nature of the solutions. First, the MSS condition $|h_2| < \frac{1}{\sqrt{p_{22}}}$ determines the extent of flexibility in policies, that is, the admissible "timid" and "substantial" deviations that permit the relaxation of Leeper's (1991) original conditions. In this respect, the persistence of the regime (i.e. p_{22}) plays a key role, as evident from the definitions of $\bar{\gamma}_{\tau,2}$ and $\bar{\gamma}_{\pi,2}$.

Second, as the absorbing regime is AM/PF, given (23), we know from Leeper (1991) that the only stable solution for this regime implies $g_{\pi,1} = 0$.[12] As for the fixed-coefficient New Keynesian model, this solution for the AM/PF regime has no wealth effects. Then, given (19) and (21) it is easy to show that the upper-right zone in Figure 3a admits only one stable Ricardian solution for the second regime (i.e. $g_{\pi,2} = 0$), while the lower-left zone admits only one stable non-Ricardian/FTPL solution for the second regime (i.e., $g_{\pi,2} \neq 0$). It follows that in the upper-right zone the only stable solution (h_1, h_2) for the whole Markov-switching model implies Ricardian dynamics in both regimes, while in the lower-left zone it implies FTPL dynamics in the second regime.

Figure 3b shows that the general case in which both regimes are non-absorbing ($p_{11}, p_{22} < 1$) exhibits the same qualitative results.[13] In particular, it remains true that the unique stable solution in the upper-right zone is the Ricardian solution, and hence, the dynamics will show no wealth effects in either regime. In contrast, the unique stable solution in the lower-left zone is the non-Ricardian one, and hence, the dynamics of the system will have wealth effects in both regimes.

[12] As the value of $\gamma_{\pi,1}$ is greater than 1, no value of $h_1 < 1$ exists, such that the square bracket in (23) is equal to zero.

[13] As Appendix A.5 shows, in the general non-absorbing case with our calibration, the threshold values for the fiscal policy coefficient are $-0.02 < \gamma_{\tau,2} < 3.93$.

3.4. The need for coordination within and *across* regimes: a new taxonomy

The general message from this analysis is that when monetary policy varies timidly, determinacy of the global equilibrium requires that fiscal policy also varies timidly. By contrast, when monetary policy varies substantially, determinacy generally requires fiscal policy to also vary substantially. In a Markov-switching context, monetary and fiscal policies need to coordinate not only within regimes, as suggested by Leeper (1991), but even across regimes. We find that policies need to be overall balanced to guarantee the existence of a unique stable equilibrium. The analysis thus naturally provides a new taxonomy to define both the number and the types of equilibria that could arise when monetary and fiscal policies interact in a Markov-switching context. Two different scenarios are of particular interest. First, overall active monetary policies require overall passive fiscal policies to yield determinacy. This *overall AM/PF mix* allows a limited degree of flexibility for both monetary and fiscal policy and generates a unique Ricardian solution, with no wealth effects in either of the two regimes. Second, switching monetary policies must be paired with switching fiscal policies to yield determinacy. This *overall switching mix* generates a unique non-Ricardian solution, which implies wealth effects and FTPL dynamics in both regimes. The scheme in Panel B of Table 1 summarises these results.

3.4.1. The importance of coordination *across* regimes

Leeper (1991) is the seminal paper on the importance of coordination between monetary and fiscal policies. However, his taxonomy is defined for a fixed-coefficient model and does not provide any guidance in a Markov-switching context. In such a framework, coordination is not merely a question of being active or passive, but the extent to which policies are active or passive across regimes is essential. Moreover, the expectation of a stable regime in the future is not *per se* sufficient to achieve determinacy, or nothing ensures that switching between two regimes, which are determinate in a fixed-coefficients context, yields determinacy. Similar to the Leeper's (1991) approach in the case of fixed coefficients, our proposed taxonomy provides conditions for determinacy, but we also provide conditions for the presence (or absence) of wealth effects in both regimes.

To make this point clear, consider again Figure 3b. Point B in the upper-right zone and point A on its left return determinacy and indeterminacy, respectively. This is true even if both points exhibit the same fiscal policy in both regimes (and the same monetary policy in regime 1) and correspond to an economy that switches between an AM/PF and a PM/AF mix: two regimes that, taken in isolation, are determinate.[14] The same result obtains if one compares point B_1 in the lower-left zone and point

[14]The coordinates of the points in Figure 3b are A: ($\gamma_{\pi,2} = 0.9$; $\gamma_{\tau,2} = 0$); B: ($\gamma_{\pi,2} = 0.97$; $\gamma_{\tau,2} = 0$); B_1: ($\gamma_{\pi,2} = 0.9$;

A, characterised by the same monetary policy in both regimes (and the same fiscal policy in regime 1). To explain these apparently puzzling findings, we exploit our taxonomy and the MPF and FPF concepts. Points A and B entail the same timid deviation in regime 2 from the passive fiscal policy under regime 1, and thus, they are both characterised by an *overall PF*. To have determinacy of the global equilibrium, monetary policy should also vary timidly in regime 2, to have an *overall AM*. This does not happen at point A, as monetary policy is insufficiently active, while it does at point B (which indeed lies in the determinate area in Figure 2a). Point B is above both the MPF and the FPF, that is, it satisfies both the long-run Taylor principle and the long-run fiscal principle. Point A satisfies only the latter. Compare now points A and B_1. As these two points share the same substantial deviation in regime 2 from the active monetary policy under regime 1, they do not satisfy the long-run Taylor principle, yielding a *switching monetary policy*. To have determinacy of the Markov-switching system, fiscal policy is also required to switch, i.e., to vary substantially. This is not the case for point A, which lies above the FPF, as fiscal policy is only timidly active, and thus, fiscal policy is *overall PF*. In contrast, this is the case for point B_1, which is below the FPF (and thus lies in the determinate area in Figure 2b).

Furthermore, determinacy could arise from very different policy mixes. Switching from a double active regime (AM/AF, explosive in fixed coefficients) to a double passive one (PM/PF, indeterminate in fixed coefficients) can return determinacy. Consider, for example, point C in Figure 2a and point D in Figure 2b. They share the same fiscal policy coefficients, satisfying the long-run fiscal principle above the FPF: a passive fiscal policy under regime 2 and a timid deviation from it under regime 1 (i.e., an *overall PF*). In both cases, monetary policy is active in the first regime and passive in the second. In Leeper's (1991) taxonomy, this would be a shift from a double active to a double passive regime that returns determinacy in Figure 2a but not in Figure 2b. According to our interpretation, this is because at point C the overall monetary and fiscal policy mix is balanced (i.e, there is also a timid change in monetary policy that satisfies the long-run Taylor principle, and thus, we are in the case of *overall AM/PF*), while at point D it is not (there is a substantial change in monetary policy, which is *switching*).

A second important aspect of the importance of coordination across regimes regards the validity of the long-run Taylor principle disclosed by Davig and Leeper (2007b). Bringing fiscal policy into the picture shows that the long-run Taylor principle is conditional on fiscal policy behaviour: it holds only if the fiscal policy mix is *overall PF*. The long-run Taylor principle fails when fiscal policy is not

$\gamma_{\tau,2} = -0.05$).

overall passive, as, for example, at a point in the dark blue region of Figure 2a.

3.5. The expectation effects of regime shifts

This section considers, in greater detail, the dynamics implied by the different solutions to illustrate the link with our proposed taxonomy, the determinacy analysis and the role of expectation effects. Cross-regime spillovers characterise the dynamics in a Markov-switching framework, as the economy's equilibrium properties are contaminated by both the characteristics of the other regimes and the probability of shifting between the alternative regimes. Davig and Leeper (2008) define expectation effects as the difference between the equilibrium outcomes of a model with fixed coefficients and those of a model that accounts for expected changes in regimes.

Recall that we identified two sets of determinate parametrizations: an *overall AM/PF* mix that yields Ricardian dynamics in both regimes and an *overall switching* mix that implies wealth effects in both regimes. Points B and B_1 in Figure 3b are examples of these two types of solutions. Both are characterised by a shift from the same AM/PF regime to a PM/AF regime with transition probabilities $p_{11} = p_{22} = 0.95$, and they both return determinacy. While point B entails a timid deviation of both monetary and fiscal policy from the AM/PF regime, for point B_1 the deviation is substantial. As a consequence, point B is an overall AM/PF mix (see Figure 2a), and point B_1 is an overall switching mix (see Figure 2b). Figure 4 shows the impulse responses to a positive fiscal shock (i.e., an unexpected reduction in lump-sum taxes) for the policy combinations implied by points B and B_1 (panels a and b, respectively).[15] The impulse response functions are conditional on remaining in the particular policy regime in place, and thus, each panel displays two columns of graphs corresponding to each of the two regimes. Moreover, to highlight the expectation effects, each panel in Figure 4 displays two lines: the dashed lines are the responses of the variables under a fixed-coefficients model, while the solid lines are the responses under a Markov-switching model. The difference between the solid and the dashed lines in each graph represents the expectation effects.

For the *overall AM/PF mix* (i.e., point B) we have the following:

1. The solid lines across the two regimes in Figure 4a are coincident except for the path of debt. The possibility of moving towards a regime with Ricardian dynamics makes the impulse responses also behave as Ricardian in the PM/AF regime (i.e., inflation does not increase).

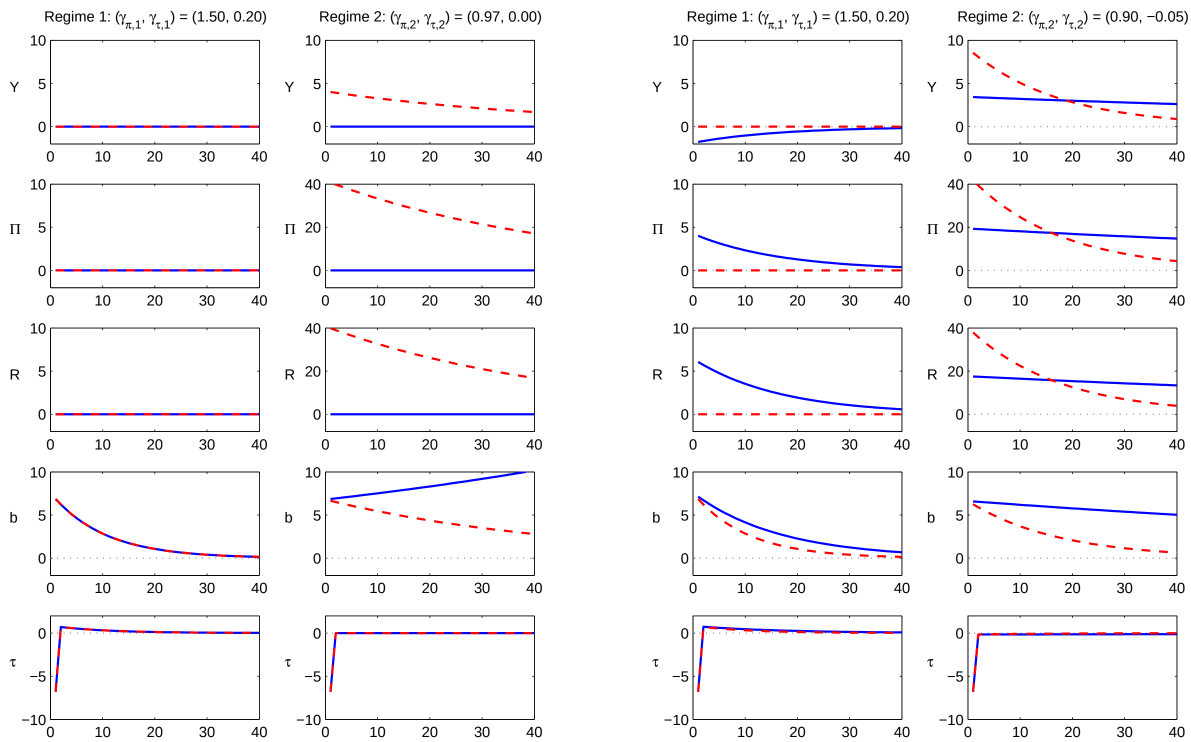
[15] Recall that the policy combinations for point B are ($\gamma_{\pi,1} = 1.5; \gamma_{\tau,1} = 0.2$) in regime 1 and ($\gamma_{\pi,2} = 0.97; \gamma_{\tau,2} = 0$) in regime 2. For point B_1 we have ($\gamma_{\pi,1} = 1.5; \gamma_{\tau,1} = 0.2$) in regime 1 and ($\gamma_{\pi,2} = 0.9; \gamma_{\tau,2} = -0.05$) in regime 2.

2. Now consider the differences between the solid and dashed lines. The expectation effects are asymmetric in the two regimes. In the AM/PF regime, the expectations effects are absent, as there is no difference between these two lines.

Regarding the *overall switching mix* (i.e., point B_1) we have the following:

1. The solid lines no longer coincide. In contrast to the previous case, the possibility of switching to a PM/AF regime makes the impulse responses non-Ricardian also in the AM/PF regime: wealth effects are at work in both regimes, and inflation now increases under both regimes.

2. The expectation effects are again asymmetric, and there are now wealth effects under the AM/PF regime.



(a) Overall AM/PF regime

(b) Overall switching regime

Figure 4: Impulse response function to a positive fiscal shock.
Notes: Regimes are recurrent, with $p_{11} = p_{22} = 0.95$. Blue solid lines: Markov-switching model; red dashed lines: fixed coefficients model.

Why do impulse responses for these two points, which entail a switch from an AM/PF to a PM/AF regime, return such strikingly different results?[16] Our analysis above explains the underlying

[16] Both results of asymmetric expectation effects and the coincidence of the solid lines under point B but not under point B_1 hold even when considering a monetary policy shock. These results are available from the authors upon request.

mechanisms that drive these findings. We labelled an overall AM/PF mix one in which only timid deviations from AM/PF are allowed. In this case, there is only one type of admissible stable solutions: those above the FPF in Figure 2a. However, as implied by Proposition 1, we know that these solutions yield Ricardian dynamics in both regimes. The possibility of switching to the AM/PF regime, once in a PM/AF regime, is here sufficient to stabilise inflation under both regimes. The cross-regime spillover of the AM/PF regime dominates and its dynamics pass through to the PM/AF regime. As a result, the two regimes behave identically, except for the path of debt, because conditional on the PM/AF regime, taxes do not increase to stabilise the debt. Conversely, for an overall switching mix, Figure 2b shows that determinacy requires both policies to substantially switch across regimes, and the unique stable solutions in this case exhibit non-Ricardian dynamics under both regimes. The possibility of switching to the AM/PF regime is in this case not sufficient to stabilise inflation under both regimes. The cross-regime spillover of the PM/AF regime dominates, and its dynamics pass through to the AM/PF regime. Thus, there are wealth effects in both regimes: inflation increases under both regimes, and fiscal policy thus undermines the ability of monetary policy to control inflation. Inflation increases less under the AM/PF regime due to the reaction of monetary policy. In this case, the expansionary fiscal policy steps on a rake, as monetary policy causes a recession by raising the nominal interest rate in the attempt to control inflation.

Finally, do wealth effects disappear if agents are confident in a once-and-for-all switch to an AM/PF regime? We find that under an overall AM/PF mix, the impulse responses are identical to those in Figure 4a even if the AM/PF regime is absorbing, i.e. $p_{11} = 1$. Conversely, in the overall switching mix case with an absorbing AM/PF regime, the impulse responses in the PM/AF regime do not differ from those in the non-absorbing case. Our new taxonomy explains that the expectation of an absorbing AM/PF regime for the future is neither a necessary nor a sufficient condition to avoid wealth effects in the PM/AF regime. It is not necessary because we do not find wealth effects in the overall AM/PF case even when $p_{11} = p_{22} = 0.95$ (see Figure 4a). It is not sufficient because we find wealth effects in the PM/AF regime in the overall switching case even when the AM/PF regime is absorbing.

4. Some theoretical and policy implications

Our framework and methodology has several implications, and it can rationalise some apparently contradictory results in the literature.

First, our new taxonomy provides an answer to the problem of establishing whether a regime is

Ricardian in a model in which agents are aware of recurrent regime changes. In a Markov-switching context, as Bianchi and Melosi (2014) note, the policy mix according to Leeper's (1991) taxonomy is insufficient to establish whether a regime is Ricardian. However, we find that neither expectation effects nor wealth effects are present under an AM/PF regime when agents expect a regime shift and the policy mix is *overall AM/PF*. Even more so, an *overall AM/PF* mix is definitively Ricardian in both regimes AM/PF and PM/AF.

Second, the overall AM/PF mix is consistent with the case advanced by Krugman (2014) of a "timidity trap". Take an unbacked fiscal expansion engineered to escape a liquidity trap. If that PM/AF policy deviates only timidly from the previous AM/PF regime, that is, if the policy action is too timid, it would not bring about the wealth effects needed to reflate the economy. To have the desired effects, there should be a clear departure from the previous regime, hence an overall switching mix.[17]

Third, our results are consistent with Liu et al. (2009) who analyse regime shifts in monetary policy in a context of an always-passive fiscal policy and find that the expectation effects are asymmetric.[18] The shift from a dovish (or less hawkish) monetary regime to a hawkish one reduces inflation volatility to a greater extent than an inverse shift raises it: *inflation-anchoring expectations* prevail.

Our methodology does not replicate the findings in Chung et al. (2007) that fiscal theory is always at work when agents assign a positive probability of moving towards active fiscal policy (e.g., point B). This is because our method and stability concept are different. MSS stability accepts as equilibrium all paths with stationary first and second moments, taking into account the possibility of regime changes. We believe that this is a highly relevant concept because it is coherent with the standard transversality condition that requires equilibrium paths to be bounded in expectation. However, it follows that MSS does not impose stationarity of all regimes taken in isolation, and hence, it does not exclude temporary explosive dynamics. Nonetheless, agents' expectations are still finite at every horizon, as agents take into account the possibility of regime changes in forming their forecasts. As such, MSS could rationalise episodes such as hyperinflation or bubble boom-and-bust dynamics. In our case, MSS admits as equilibrium a temporary explosive path for the level of debt as in Figure 4a. Conditional on staying in regime 2 the debt level would explode, but the probability of staying in a given regime for long periods tends quickly to zero. A stationary solution would exist if temporary explosive dynamics were not too persistent. Chung et al. (2007) employ bounded stability, an alternative stability concept

[17] Appendix A.8 shows that this insight is particularly relevant for the recent zero lower bound episode.

[18] This result holds even if the two regimes have the same transition probabilities.

that instead excludes temporarily explosive paths.[19] Following Foerster (2016), to highlight how our results change when such equilibrium paths are not considered, we use a more tractable but related concept: "both regime stable" (BRS), where the only admissible equilibria imply $h_i < 1$ for $i = 1, 2$.[20] h_i would generally depend on all the policy coefficients and the probabilities of switching. However, the Ricardian solution in Proposition 1 is defined by $\bar{h}_i(\gamma_{\tau,i})$ and thus depends only on fiscal policy coefficients, not on both the probabilities of switching and the monetary policy coefficients. Hence, the BRS condition $h_i < 1$ simply coincides with the standard passive fiscal policy condition in each single regime i, rather than with the MSS condition (22). It follows that BRS excludes any flexibility in fiscal policy and the FPF will be defined by Leeper's (1991) passive fiscal policy conditions, as usual. Point B would not be within the FPF because it implies paths with explosive debt levels, despite that being an extremely unlikely event.[21]

Furthermore, our paper is consistent with the results in Bianchi and Melosi (2014) who find that after a deficit shock under an AM/PF regime or under a short-lasting deviation towards a PM/AF regime, there are no effects on inflation (or output). Inflation and output, however, increase under a long-lasting deviation towards the same PM/AF. As both the short- and the long-lasting deviations are towards the same PM/AF, the authors identify regime persistence as the key determinant to establish whether a regime is Ricardian.[22] Our taxonomy is consistent with this finding because, although we have not focused on the role of transition probabilities thus far, our definitions of timid deviation and overall mix depend on them (see Section 3.3.1). Consider a numerical example in the case of the overall switching mix described by point B_1, reported as a black dot in Figure 5. Under this policy combination, if the second regime is long-lasting, say $p_{22} = 0.95$, a timid deviation is defined by $\gamma_{\tau,2} \in [-0.021; 0.02]$ and $\gamma_{\pi,2} \in [0.955; 1]$. Instead, if regime 2 is less persistent, say $p_{22} = 0.8$, a timid deviation is defined by $\gamma_{\tau,2} \in [-0.16; 0.02]$ and $\gamma_{\pi,2} \in [0.67; 1]$.[23] Therefore, with a long-lasting deviation, B_1 would correspond to an overall switching mix (see Figure 5a), while with a less permanent deviation we would have an overall AM/PF regime (see Figure 5b). In the first case, the

[19]See their analytical example.

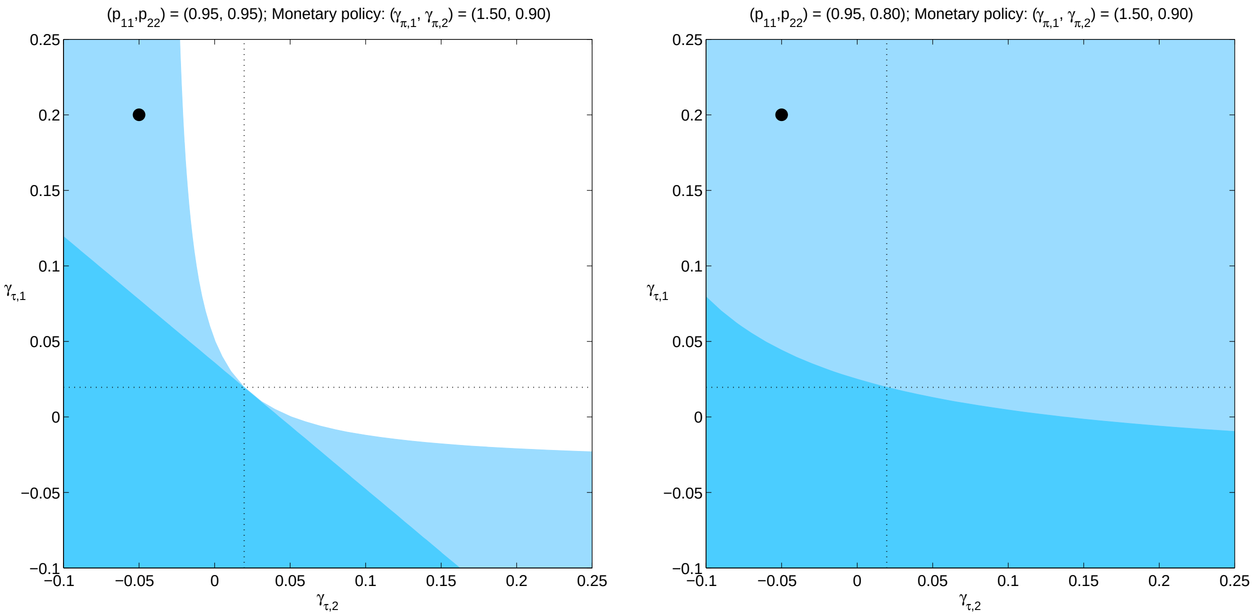
[20]See the discussion on p. 217 in Foerster (2016). Note that BRS is a necessary, but not sufficient condition for bounded stability.

[21]See Appendix A.7 for a representation of how the monetary and fiscal frontiers change when the BRS stability concept is employed.

[22]See also Bianchi and Ilut (2017) on this point. They do not find any effect of a tax shock on inflation when the AM/PF regime is perceived to be fully credible (if agents expect to remain there forever) or if, being in a PM/AF regime, agents are confident in a return to the AM/PF regime.

[23]These intervals can be obtained following the procedure in Section 3.3.1 and in Appendix A.5.

impulse responses to a fiscal shock would display a hike in inflation (see Figure 6a) because the unique stable solution is the non-Ricardian one. In the second, there would not be inflationary effects (see Figure 6b) because the unique stable solution is the Ricardian one.

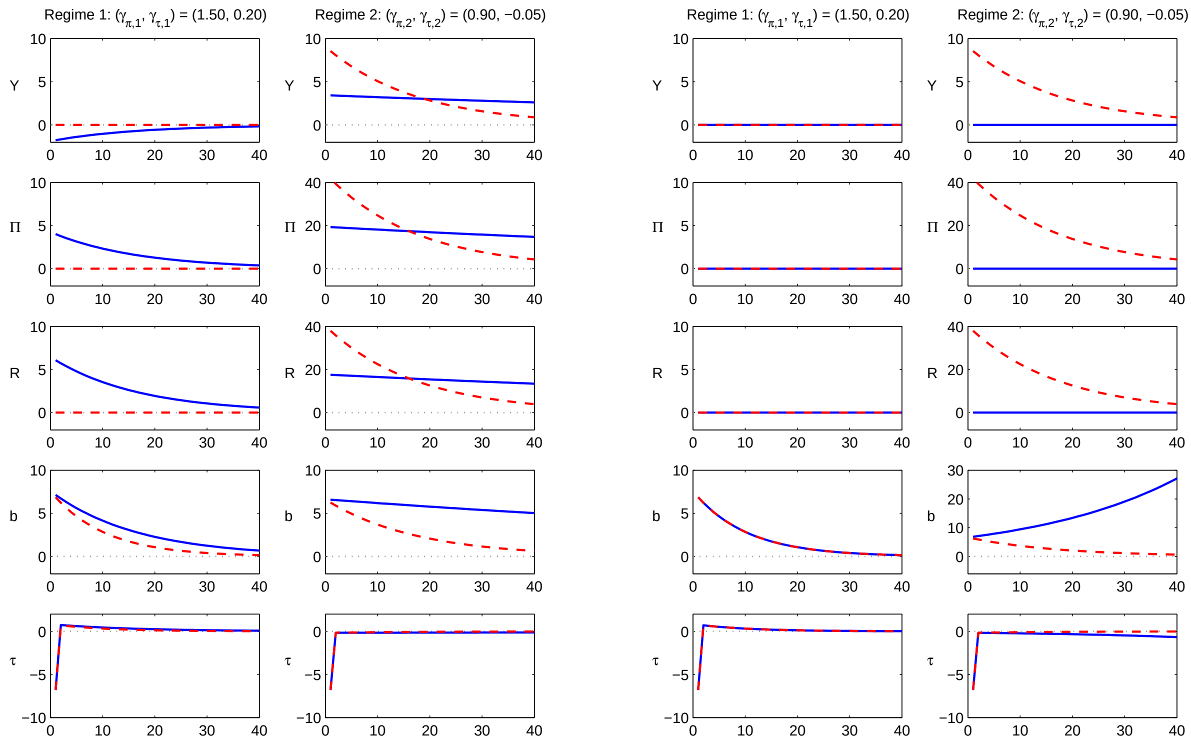


(a) $p_{22} = 0.95$ (b) $p_{22} = 0.80$

Figure 5: The monetary policy frontier for different levels of persistence of regime 2.
Notes: Light blue: unique solution; white: indeterminacy; dark blue: explosiveness.

This analysis could have notable consequences for monetary policy, for both the timing of any exit strategy and forward guidance. During the recent crisis, the accumulated credibility of the Federal Reserve permitted well-anchored inflation expectations, despite that the U.S. was potentially in a PM/AF regime. If we are prepared to believe that during the crisis monetary policy deviated substantially from an AM regime, then the only way to avoid a future spike in inflation is to make this deviation short-lasting. A long-lasting deviation, conversely, could either de-anchor inflation expectations and make inflation unavoidable or generate multiple solutions, depending on the behaviour of fiscal policy. Indeed, if fiscal policy remains only timidly active, it may be difficult for policy makers to predict an inflationary surge, as both the Ricardian and the non-Ricardian solutions are admissible. An inflationary surge would be possible in the latter case. If we believe this scenario to be the relevant one, then it might be that the observed subdued path of inflation is due to agents coordinating on a Ricardian solution. However, these dynamics could abruptly revert into an inflation upswing if expectations about the behaviour of fiscal policy were to suddenly switch.

From a related perspective, the fact that central banks brought target rates to zero represents a



(a) $p_{22} = 0.95$

(b) $p_{22} = 0.80$

Figure 6: Impulse response function to a positive fiscal shock for different levels of persistence of regime 2.

Notes: Blue solid lines: Markov-switching model; red dashed lines: fixed coefficients model.

very special case of passive monetary policy, as interest rates do not move when inflation changes. In Appendix A.8 we report two applications of our results to the ZLB case. First, imagine being in a recession with interest rates stuck at the ZLB and agents expecting a return, at some point in the future, to the traditional AM/PF regime. How should fiscal policy be set in the current regime to guarantee determinacy? We find that the equilibrium is indeterminate when the ZLB regime is short-lasting, irrespective of fiscal policy. Determinacy is obtained only if agents expect the ZLB to last for a long time and to be accompanied by active fiscal policy. This result stresses the importance of "forward guidance", on both the monetary and fiscal side. Agents must be convinced of a long-lasting PM/AF regime both through the promise of a long period of zero interest rates and a long deferral of fiscal consolidation. The second exercise investigates the policy mix in place in the U.S. during the ZLB period. A Bayesian VAR, fitted on quarterly data for the sample 2008q4-2015q4, returns impulse responses consistent with the PM/AF regime in an overall AM/PF mix: output and inflation do not move, while real debt increases (second column of Figure 4a). We argue that the dynamics remained Ricardian due to timidity of fiscal policy: our model suggest that the U.S. authorities could well have been caught in a “timidity trap”.

5. Conclusions

This paper studies the determinacy properties of the equilibrium in a New Keynesian model when both monetary and fiscal policies may switch according to a Markov process. Nothing ensures that the switching between two regimes, which would be determinate under a fixed-coefficient framework, returns determinacy. Davig and Leeper (2007b) define the *long-run Taylor principle* as the condition that the coefficients in the Markov-switching Taylor rule need to satisfy to guarantee a unique equilibrium, given passive fiscal policy. This can be graphically visualised as a monetary frontier. Equivalently, we define a fiscal frontier that visualises the *long-run fiscal principle* as the condition that the coefficients in the Markov-switching government tax rule need to satisfy to guarantee a unique equilibrium, given active monetary policy. We find that the long-run Taylor principle ensures determinacy not only with an always-passive fiscal policy, as Davig and Leeper (2007b) maintain, but also when it deviates timidly into active fiscal territory for some time, provided that the long-run fiscal principle is satisfied.

For the economy to exhibit a unique stable rational expectations equilibrium, monetary and fiscal authorities should coordinate not only within regimes as suggested by Leeper (1991), but also *across regimes* by choosing the extent of activeness or passiveness. Hence, we propose a new taxonomy that generalises the seminal paper of Leeper (1991) to a Markov-switching context. We name a timid deviation from an active monetary policy into passive monetary territory that respects determinacy—i.e., that satisfies the long-run Taylor principle—an “overall active monetary policy”. Symmetrically, a timid deviation from a passive fiscal policy into active fiscal territory—i.e., that satisfies the long-run fiscal principle—is named an “overall passive fiscal policy”. Substantial shifts in monetary and fiscal policies are termed “switching policies”. Monetary and fiscal policies need to be overall balanced to guarantee a unique equilibrium: overall active monetary policies need to be coupled with overall passive fiscal policies (i.e., an overall AM/PF mix), and switching monetary policies with switching fiscal policies (i.e., an overall switching policy mix).

Our new taxonomy also establishes an explicit link between the determinacy analysis and the dynamic behaviour of a Markov-switching DSGE model. If the policy mix is overall switching, then the fiscal theory of the price level is always at work. This is not true if the policy mix is overall AM/PF. In this latter case, there are no wealth effects because fiscal policy deviates timidly into the active territory remaining, nevertheless, overall passive. As a result, timid deviations from the AM/PF benchmark keep fiscal expectations anchored and avoid wealth effects, allowing the central bank to maintain inflation under control. Moreover, the expectation of a fully credible (even absorbing) AM/PF regime for the future is neither a necessary nor a sufficient condition to avoid wealth effects under a PF/AM regime.

Our framework has a number of policy implications that we discussed in Section 4. In particular, with the lens of the model, the U.S. economy could have been in a "timidity trap" and an indeterminate equilibrium during the crisis. An important implication for the ability of the central bank to control inflation is that there could be an inflation upswing if the expectations regarding the behaviour of fiscal policy were to suddenly switch in a substantial way.

The analysis suggests some directions for future research. Our results are based on a very simple New Keynesian model. The advantage of such a framework is to allow us to obtain a number of analytical results, to gain insightful intuitions into what drives determinacy and the linkage among determinacy, dynamics, expectation effects and wealth effects. The natural next step in this line of research would be to determine the extent to which our new taxonomy and results help to interpret the numerical results in a more realistic, and possibly estimated, DSGE model. Finally, our definition of timid deviation has the same flavour as Leeper and Zha's (2003) definition of "modest policy interventions." However, our definition is based on the determinacy region of the parameter space and not on their modesty statistic. Empirically evaluating whether these definitions are consistent could be a fruitful avenue for future research.

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