Macroeconomic Policies and Equilibrium Determinacy*

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Abstract

This paper studies the issue of equilibrium determinacy under monetary and fiscal policy feedback rules in an optimizing general equilibrium model with overlapping generations and flexible prices. It is shown that equilibria may be determinate also when monetary and fiscal policies are both "passive". In particular, under passive monetary rules equilibrium uniqueness is more

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likely to be verified when fiscal policies are less committed to public debt stabilization.

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1 Introduction

The issue of equilibrium determinacy under simple monetary policy rules is a debated topic in monetary theory. Following the original paper by Taylor (1993), the modern literature typically studies the question of equilibrium uniqueness under the assumption that monetary policy adopts Taylor-style interest rate rules, which appear to describe consistently the behavior of several Central Banks (see, e.g., Clarida, Galì and Gertler, 1998, 2000, Judd and Rudebusch, 1998, Taylor, 1999, Gerlach and Schnabel, 2000, and Orphanides, 2001, 2003). Notably, the major requirement for equilibrium uniqueness within forward looking optimizing general equilibrium models with infinite horizon is the so-called Taylor principle, i.e., the prescription that monetary authorities should raise the short-term nominal interest rate more than proportionally to increases in inflation (see, e.g., Clarida Galì and Gertler 1999, Carlstrom and Fuerst, 2000, Bullard and Mitra, 2002, Woodford, 2001a, 2003 and McCallum, 2003).[1] The respect of this requirement implies that the

[1] A discussion on the possibility of global indeterminacies under "active" interest rate rules in a continuous time framework is provided by Benhabib, Schmitt-Grohé and Uribe (2001a, 2001b).

real interest rate will be moved upward when inflation exceeds its target.

However, it should be emphasized that in order to ensure equilibrium determinacy the Taylor principle should be coupled with a "passive" fiscal policy, constrained to guarantee a stable path for the real public debt for any bounded sequence of all remaining endogenous variables. Otherwise, in the case of an "active" fiscal policy, equilibrium uniqueness requires the violation of the Taylor principle. This is consistent with the original result obtained by Leeper (1991).[2][3]

The main contribution of this paper is to extend this line of research to the case of a general equilibrium optimizing model involving overlapping generations. An advantage of our framework is that it is more general, since it permits to treat the infinite horizon setup as a special case. In order to compare our results with those obtained by Leeper (1991), we maintain the hypothesis of flexible prices and endowment economy. The analysis emphasizes the role of fiscal variables in affecting the necessary and sufficient conditions yielding unique paths for the endogenous variables for any sequence of all exogenous variables. Equilibrium uniqueness depends not only on the parameter reflecting the response of monetary policy to inflation, but also on the degree of reaction of fiscal policy to the stock of public

[2] The implications in terms of price level determinacy under fiscal policies that do not satisfy the solvency condition for all sequences of the price level are developed by the so-called "fiscal theory of the price level" (see Sims, 1994 and Woodford, 1994, 1995, 2001b).

[3] See Woodford (2003) for a discussion within New Keynesian frameworks.

debt. We demonstrate that wealth effects make policy regimes in which both monetary and fiscal policies are passive compatible with the uniqueness of equilibrium. Moreover, a prediction of the model is that the capability of passive monetary rules relatively to active monetary rules in ensuring equilibrium determinacy increases when combined with a lower reactiveness of fiscal policy to public debt.

The scheme of the paper is the following. Section 2 describes the general equilibrium optimizing model. In Section 3 we consider a log-linear approximation of all equilibrium conditions around a zero inflation steady state. Section 4 specifies the definitions of "active" and "passive" monetary and fiscal policies. Section 5 illustrates the baseline calibration of the model. In Section 6 we derive analytically the conditions that exhibit equilibrium determinacy. Section 7 summarizes the main conclusions.

2 The model

In this Section, we develop a discrete time version of the Yaari (1965) - Blanchard (1985) overlapping generations model, with no intergenerational bequest motive extended to include money holdings choice.

All agents have identical preferences, face the same, constant probability of death, ϑ, and there is no population growth. As in Blanchard (1985), competitive insurance companies collect financial wealth from the deceased members of a cohort and make premium payments to survivors at the beginning of each period.

Each agent of generation s uses its inelastically supplied labor to produce $y_{s,t}$ units of fully perishable output in each period $t \geq s$. Labor income and lump-sum net taxes are assumed to be equally distributed across agents. The objective of the representative agent belonging to the generation born at time $s \leq 0$ is to maximize her expected lifetime utility

$$\sum_{t=0}^{\infty} \beta^t (1-\vartheta)^t \ln \left[c_{s,t}^{\alpha} \left(\frac{m_{s,t}}{P_t} \right)^{1-\alpha} \right], \tag{1}$$

subject to the flow budget constraint

$$m_{s,t} + R_t^{-1} b_{s,t+1} = \frac{1}{1-\vartheta} \left(b_{s,t} + m_{s,t-1} + P_t y_{s,t} - t_{s,t} - P_t c_{s,t} \right), \tag{2}$$

where $\alpha \in (0,1)$, $\beta \in (0,1)$ is the subjective discount factor, P_t is the price level, R_t is the gross nominal interest rate on bonds, $m_{s,t,}$ $b_{s,t}$, $t_{s,t}$, $c_{s,t}$ denote nominal money balances, nominal riskless government bonds carried over from period $t-1$ and paying one unit of numéraire in period t, lump-sum net taxes and consumption, respectively. The short-term nominal interest rate is controlled by the monetary authority. Note that the flow budget constraint incorporates the return on the insurance contract, $(1-\vartheta)^{-1}$.

The solution to the individual intertemporal maximizing problem yields the Euler equation and the efficient condition on money demand choice, respectively:

$$\frac{c_{s,t+1}}{c_{s,t}} = \beta R_t \frac{P_t}{P_{t+1}}, \tag{3}$$

$$m_{s,t} = \frac{(1-\alpha)}{\alpha(1-\vartheta)} \frac{R_t}{R_t - 1} P_t c_{s,t}. \tag{4}$$

To derive a closed form solution for individual consumption, note that the budget constraint (2) can be written as

$$\rho_{t,t+1} a_{s,t+1} + \frac{R_t - 1}{R_t} m_{s,t} = \frac{1}{(1-\vartheta)} \left(a_{s,t} + P_t y_{s,t} - t_{s,t} - P_t c_{s,t} \right), \tag{5}$$

where $a_{s,t} = b_{s,t} + m_{s,t-1}$ denotes total wealth at the beginning of period t and $\rho_{t,t+1} = R_t^{-1}$ is the discount factor satisfying $\rho_{t,\tau} = \prod_{j=t+1}^{\tau} \rho_{j-1,j}$ (with $\rho_{t,t} = 1$). The intertemporal budget constraint is obtained iterating forward (5) and imposing the transversality condition precluding agents' Ponzi-games, $\lim_{\tau \to \infty} \rho_{t,\tau} a_{s,\tau} = 0$:

$$\begin{aligned} & \sum_{\tau=t}^{\infty} \rho_{t,\tau} (1-\vartheta)^{\tau-t} \left[P_\tau c_{s,\tau} + (1-\vartheta) \frac{R_\tau - 1}{R_\tau} m_{s,\tau} \right] \qquad (6) \\ = \quad & a_{s,t} + \sum_{\tau=t}^{\infty} \rho_{t,\tau} (1-\vartheta)^{\tau-t} \left(P_\tau y_{s,\tau} - t_{s,\tau} \right). \end{aligned}$$

Substituting both the forward solution of (3) and the money demand choice into (6), individual consumption can be written as a fraction of total wealth:

$$P_t c_{s,t} = \alpha \left[1 - \beta (1-\vartheta) \right] \left[a_{s,t} + \sum_{\tau=t}^{\infty} \rho_{t,\tau} (1-\vartheta)^{\tau-t} \left(P_\tau y_{s,\tau} - t_{s,\tau} \right) \right]. \tag{7}$$

Aggregating over all cohorts of consumers and using the fact that the financial wealth of newly born agents is zero, $a_{t,t} = 0$, one obtains the aggregate budget constraint, the aggregate money demand and the aggregate consumption function, respectively:

$$\rho_{t,t+1} A_{t+1} = A_t + P_t Y_t - T_t - P_t C_t - \frac{R_t - 1}{R_t} M_t, \tag{8}$$

$$M_t = \frac{(1-\alpha)}{\alpha} \frac{R_t}{R_t - 1} P_t C_t, \tag{9}$$

$$P_t C_t = \alpha \left[1 - \beta \left(1 - \vartheta\right)\right] \left[A_t + \sum_{\tau=t}^{\infty} \rho_{t,\tau} \left(1-\vartheta\right)^{\tau - t} \left(P_\tau Y_\tau - T_\tau\right)\right], \tag{10}$$

where aggregate values are the sum across cohorts, weighted by their respective sizes, $A_t = \sum_{s=-\infty}^{t} \vartheta \left(1-\vartheta\right)^{t-s} a_{s,t}$, $Y_t = \sum_{s=-\infty}^{t} \vartheta \left(1-\vartheta\right)^{t-s} y_{s,t}$, $T_t = \sum_{s=-\infty}^{t} \vartheta \left(1-\vartheta\right)^{t-s} t_{s,t}$, $M_t = \sum_{s=-\infty}^{t+1} \vartheta \left(1-\vartheta\right)^{t+1-s} m_{s,t}$, and $C_t = \sum_{s=-\infty}^{t} \vartheta \left(1-\vartheta\right)^{t-s} c_{s,t}$. The transversality condition in aggregate terms is $\lim_{\tau \to \infty} \rho_{t,\tau} A_\tau = 0$, where $A_t = B_t + M_{t-1}$.

Using (8) and (9) into (10) yields the dynamic equation for consumption:

$$P_{t+1} C_{t+1} = \beta R_t P_t C_t - \frac{\alpha \vartheta \left[1 - \beta \left(1-\vartheta\right)\right]}{\left(1-\vartheta\right)} A_{t+1}. \tag{11}$$

Aggregate consumption is a function not only of expected consumption, but also of aggregate non-human wealth. In the case of an immortal representative agent setup ($\vartheta = 0$), one obtains the standard Euler equation on consumption.

The government issues riskless one-period pure discount bonds, B_t^s. Public debt in nominal terms evolves in accordance with the flow government budget constraint:

$$R_t^{-1} B_{t+1}^s = B_t^s - T_t - \left(M_t^s - M_{t-1}^s \right), \tag{12}$$

where M_t^s denotes money supply. For simplicity, and without loss of generality, we have normalized government expenditures to zero.

In equilibrium, money balances demanded by private agents equal the money supplied by the government, $M_t = M_t^s$, and the bonds demanded equal the quantity of government bonds issued, $B_{t+1} = B_{t+1}^s$. Using the money and bonds market clearing conditions, (8) and (12) imply that $C_t = Y_t$.

3 Log-linearized equilibrium conditions

This Section derives log-linear versions of all equilibrium conditions. We use lower case letters to indicate the log-deviations of the respective original variables from a steady state with zero inflation and positive public debt.

On the private sector side, after imposing the goods market clearing condition, the log-linearized versions of the aggregate money demand equation (9) and the aggregate consumption dynamic (11) are, respectively:

$$m_t^* = y_t - \psi_r r_t, \tag{13}$$

$$y_{t+1} = (1+\psi_a)(r_t - \pi_{t+1}) + (1+\psi_a)\, y_t - \psi_a \left(a^*_{t+1} - \pi_{t+1}\right), \tag{14}$$

where $\psi_r = (R-1)^{-1} - 1$, $\psi_a = \frac{\alpha\vartheta[1-\beta(1-\vartheta)]}{(1-\vartheta)} \frac{A}{PY}$, $m^*_t = m_t - p_t$, $a^*_{t+1} = a_{t+1} - p_t$, and $\pi_{t+1} = p_{t+1} - p_t$ is the inflation rate between $t+1$ and t. The aggregate non-human real wealth is given by

$$a^*_{t+1} = \omega_b b^*_{t+1} + \omega_m m^*_t, \tag{15}$$

where $b^*_{t+1} = b_{t+1} - p_t$, and where the parameters $\omega_b = \frac{B}{A}$ and $\omega_m = \frac{M}{A}$ represent the shares of public debt and money on total wealth, respectively.

On the public sector side, the log-linearized form of the flow government budget constraint in real terms is

$$b^*_{t+1} = r_t + R\left(b^*_t - \pi_t - \psi_\tau \tau_t\right), \tag{16}$$

where $\tau_t = t_t - p_t$ and $\psi_\tau = \frac{T}{B}$.

4 "Active" and "passive" monetary and fiscal policies

To close the system (13)-(16) we need to specify the monetary-fiscal regime. The monetary policy we consider assumes the form of a feedback interest rate rule of the Taylor-style[4]:

$$r_t = \bar{r}_t + \phi_\pi \pi_t \tag{17}$$

[4] See, for a discussion, Taylor (1993, 1999).

where $\phi_\pi \geq 0$ is the parameter reflecting the "strength" of monetary policy.

DEFINITION 1. *Monetary policy is active (passive) if and only if it satisfies (does not satisfy) the Taylor principle,* $\phi_\pi > (<)\, 1$.

Under this monetary policy regime, money is endogenous and it is residually determined.

Following Leeper (1991), fiscal policy is specified by a regime in which taxes react to the stock of real public debt. The tax rule evolves as $\frac{T_t}{P_t} = \phi_0 + \phi_b B_t^*$, where ϕ_0 and ϕ_b are policy parameters. Hence, the fiscal rule in log-linear form is given by:

$$\tau_t = \psi_\tau^{-1} \phi_b b_t^*. \tag{18}$$

After substituting the rule (18) into (16), the evolution of the real public debt is given by:

$$b_{t+1}^* = r_t + R\left[(1 - \phi_b)\, b_t^* - \pi_t\right]. \tag{19}$$

As in Woodford (2003), we assume that $R\,(1 - \phi_b) \geq 0$.

DEFINITION 2. *Fiscal policy is passive (active) or locally Ricardian (non-Ricardian) if and only if* $R\,(1 - \phi_b) < (>)\, 1$.

A passive (or locally Ricardian) fiscal policy chooses the parameter ϕ_b to guarantee a convergent path of the real public debt.

5 Parameters

Prior to deriving analytical conditions for determinacy of equilibrium, we consider the following calibrated case to illustrate our results. The average real interest rate is set equal to 4 percent. This is line with Smets and Wouters (2003) estimates for the Euro area. We let the probability of death between two consecutive periods, ϑ, be 0.1. This value should be interpreted as a measure of the individual planning horizon. The value of the average money velocity, $\frac{PY}{M}$, is set equal to 1.3. This is consistent with the Euro area average annual ratio of the GDP and the monetary aggregate M3 over the period 1994-2003. Finally, the value assigned to the steady state public debt to GDP ratio, $\frac{B}{PY}$, is assumed to meet the Maastricht criterion, 0.6. All remaining parameters of the model are implied by the steady state relations.

6 Equilibrium Determinacy

A perfect foresight equilibrium is defined as a set of processes $\{\pi_t, b_t^*, m_t^*\}$ satisfying (13)-(16) each period for any given specification of monetary and fiscal rules (17) and (18), for a given set of exogenous processes $\{y_t, \bar{r}_t\}$ and an initial value of non-human wealth a_0^*. There is a locally determinate perfect foresight equilibrium if and only if there are bounded and unique sequences for the endogenous variables for any bounded sequence for the exogenous variables.

After using the policy rules and the money demand equation, the structural equilibrium system can be represented in matrix form as

$$z_{t+1} = \mathbf{A} z_t + v_t, \tag{20}$$

where

$$z_t = \begin{bmatrix} \pi_t \\ b_t^* \end{bmatrix}, v_t = \begin{bmatrix} [(1+\psi_b) y_t - y_{t+1}] + [1 + \psi_m (1+\psi_r)] \bar{r}_t \\ \bar{r}_t \end{bmatrix},$$

$$\mathbf{A} = \begin{bmatrix} \{[1 + \psi_m (1+\psi_r)] \phi_\pi + R\psi_b\} & -\psi_b R (1-\phi_b) \\ (\phi_\pi - R) & R (1-\phi_b) \end{bmatrix},$$

with $\psi_b = \omega_b \psi_a$ and $\psi_m = \omega_m \psi_a$. The characteristic polynomial of $\mathbf{A}$ is

$$P(\lambda) = \lambda^2 - \mathrm{Tr}\mathbf{A}\lambda + \mathrm{Det}\mathbf{A}.$$

The system is composed of a non-predetermined variable, π_t, and a predetermined variable, b_t^*. According to Blanchard and Khan (1980), the existence of unique bounded solution of the system (20) requires that one root must lie outside the unit circle and one root must lie inside the unit circle. This applies to the following alternative cases:

Case I:

$$c_{11} : P(1) = 1 - \mathrm{Tr}\mathbf{A} + \mathrm{Det}\mathbf{A} > 0$$

and

$$c_{12} : P(-1) = 1 + \mathrm{Tr}\mathbf{A} + \mathrm{Det}\mathbf{A} < 0.$$

Case II:

$$c_{21} : P(1) = 1 - \mathrm{Tr}\mathbf{A} + \mathrm{Det}\mathbf{A} < 0$$

and

$$c_{22} : P(-1) = 1 + \mathrm{Tr}\mathbf{A} + \mathrm{Det}\mathbf{A} > 0.$$

We now show how traditional results are a particular case of our model.

6.1 The infinite horizon case

In the case of an immortal representative agent framework ($\psi_m, \psi_b = 0$), we have

$$\mathbf{A} = \begin{bmatrix} \phi_\pi & 0 \\ (\phi_\pi - R) & R(1 - \phi_b) \end{bmatrix}.$$

Note that the two roots are on the principal diagonal, ϕ_π and $R(1 - \phi_b)$. Therefore, the results obtained by Leeper (1991) apply. If monetary policy is active ($\phi_\pi > 1$), equilibrium uniqueness holds if and only if fiscal policy is passive ($R(1 - \phi_b) < 1$). In this case, inflation can be solved forward independently on the evolution of the government debt. Fiscal policy is concerned with determining a convergent path for the real public debt and monetary policy can pursue price stability by responding strongly to inflation.

On the other hand, under an active fiscal policy ($R(1 - \phi_b) > 1$) it is necessary for monetary policy to be passive ($\phi_\pi <

1) in order to guarantee equilibrium determinacy. Under this monetary-fiscal regime, fiscal policy does not guarantee the stability for the public debt process for each sequence of inflation. Thus, the monetary authority must accommodate fiscal policy by generating the path for the inflation rate that makes the real public debt process convergent.

6.2 The finite horizon case

In the general case of finitely-lived private agents, we can state the following proposition:

PROPOSITION 1. *Let $\phi_\pi, R(1-\phi_b) \geq 0$. When private agents are finitely-lived ($\psi_m, \psi_b > 0$), under an interest rate rule of the form (17) and a fiscal rule of the form (18) the necessary and sufficient condition for a perfect foresight equilibrium to be unique is that*

$$\begin{aligned} & \{[1+\psi_m(1+\psi_r)] - [1+\psi_m(1+\psi_r)+\psi_b] R(1-\phi_b)\} \phi_\pi \\ > \; & 1 - R(1-\phi_b) - R\psi_b. \end{aligned} \tag{21}$$

Proof. Determinacy requires that *Case I* or *Case II* applies. Note that

$$\mathrm{Det}A = \{[1+\psi_m(1+\psi_r)]\phi_\pi + R\psi_b + \psi_b(\phi_\pi - R)\} R(1-\phi_b),$$

$$\mathrm{Tr}A = \{[1+\psi_m(1+\psi_r)]\phi_\pi + R\psi_b + R(1-\phi_b)\}.$$

Take *Case II.* Since condition c_{22} is always verified given the sign restrictions, condition c_{21} is binding and holds if and only if (21) is satisfied. ■

Figure 1 plots the regions of determinacy as a function of ϕ_π and $R(1-\phi_b)$, when all other parameter values follow the baseline calibration described in Section 5. We now discuss condition (21), which includes a number of sub-cases.

6.2.1 Passive (locally Ricardian) fiscal policy

We begin with the discussion concerning locally Ricardian fiscal policy regimes. From proposition 1, we have the following corollaries.

COROLLARY 1. *If $R(1-\phi_b) \leq 1 - R\psi_b$, the necessary and sufficient condition for determinacy is*

$$\phi_\pi > \frac{1 - R(1-\phi_b) - R\psi_b}{[1+\psi_m(1+\psi_r)][1-R(1-\phi_b)] - R(1-\phi_b)\psi_b}. \quad (22)$$

Corollary 1 analyzes the case of a locally Ricardian fiscal policy in which $R(1-\phi_b) < 1 - R\psi_b$. In this case, condition (22) implies that monetary policy needs not to satisfy the Taylor principle in order guarantee determinacy of equilibrium (on the right-hand side of (22), the denominator is always greater than the numerator). This emerges also from Figure 1. The intuition leading such a result is as follows. In our framework, increases in inflation determine a redistribution of wealth from the older generations (which consume more and save less) to the younger generations (which consume less and save more). This effect tends on its own to reduce the desired aggregate spending, making a passive monetary policy that satisfies (22) well feasible. It should be noted that this result applies also in a model without public debt ($\psi_b = 0$), due to the presence of a real money balance effect ($\psi_m > 0$). Furthermore, our analytical results imply that higher values of $R(1-\phi_b)$ allow to monetary policy to respond more passively to inflation (see Figure 1).

COROLLARY 2. *If* $1 - R\psi_b < R(1-\phi_b) < \frac{1+\psi_m(1+\psi_r)}{1+\psi_m(1+\psi_r)+\psi_b}$, *the necessary and sufficient condition for determinacy is*

$$\phi_\pi \geq 0. \tag{23}$$

Corollary 2 examines the case of a passive fiscal policy such that $1 - R\psi_b < R(1-\phi_b) \leq \frac{1+\psi_m(1+\psi_r)}{1+\psi_m(1+\psi_r)+\psi_b}$. In this case, wealth effects fully work as automatic stabilizers and monetary policy can respond both passively and actively to inflation.

COROLLARY 3. *If* $\frac{1+\psi_m(1+\psi_r)}{1+\psi_m(1+\psi_r)+\psi_b} < R(1-\phi_b) < 1$, *the necessary and sufficient condition for determinacy is*

$$\phi_\pi < \frac{R(1-\phi_b) - 1 + R\psi_b}{[1+\psi_m(1+\psi_r)][R(1-\phi_b)-1] + R(1-\phi_b)\psi_b}. \tag{24}$$

Corollary 3 shows a further case in which the combination of passive fiscal policy regime with a passive monetary policy may ensure equilibrium uniqueness.

6.2.2 Unit root in the public debt process

An advantage of our model is that it enables us to deal with the special case in which the presence of a unit root characterizes the path for the real public debt. Specifically, the following corollary holds:

COROLLARY 4. *If* $R(1-\phi_b)=1$, *the necessary and sufficient condition for determinacy is*

$$\phi_\pi < R. \tag{25}$$

Under a fiscal regime affected by a unit root, monetary policy must not be aggressive in order to prevent the real government debt to follow an explosive path.

6.2.3 Active (locally non-Ricardian) fiscal policy

COROLLARY 5. *If* $R(1-\phi_b)>1$, *the necessary and sufficient condition for determinacy is*

$$\phi_\pi < \frac{R(1-\phi_b)-1+R\psi_b}{[1+\psi_m(1+\psi_r)][R(1-\phi_b)-1]+R(1-\phi_b)\psi_b} \tag{26}$$

Since the right-hand side of condition (26) is lower than one for $R(1-\phi_b) > \frac{\psi_m(1+\psi_r)+R\psi_b}{\psi_m(1+\psi_r)+\psi_b}$, under an active fiscal regime the simple violation of the Taylor principle might be not sufficient for uniqueness. Figure 1 makes clear how higher values of $R(1-\phi_b)$ require lower values of ϕ_π to induce determinacy of equilibrium.

7 Conclusions

A common criterion to select desirable monetary policy rules relies on ruling out multiplicities of solutions and instabilities. The choice of monetary policy in ensuring equilibrium uniqueness is a problem that cannot be separated from the choice of fiscal policy. In particular, a classical proposition is that active monetary rules should be coupled with passive fiscal policies and *viceversa* to ensure equilibrium determinacy. The contribution of the present paper has been to analyze the robustness of these results with respect to the introduction of a finite planning horizon for private agents. To depart from the infinite horizon hypothesis, we have utilized a micro-founded general equilibrium framework with overlapping generations. Within a Yaari-Blanchard monetary framework, it is shown that redistribution of wealth across generations alters the regions that exhibit equilibrium uniqueness. Specifically, it is feasible for monetary policy to adopt a passive rule in the presence of a fiscal regime ensuring a convergent path of the real public debt. In addition, the desirability of passive monetary rules relatively to active monetary rules in terms of equilibrium determinacy increases when fiscal rules are less committed to guarantee a stable process for the real value of public debt.

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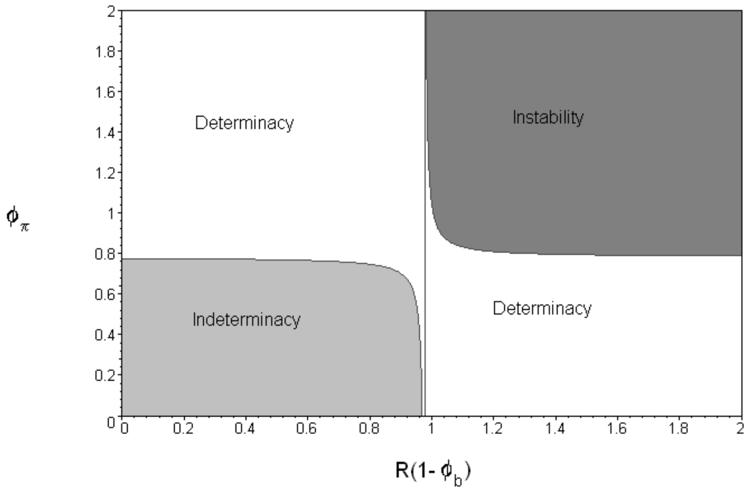

Figure 1: REGIONS OF DETERMINACY IN THE SPACE $(\phi_\pi, R(1-\phi_b))$ UNDER THE BASELINE CALIBRATION