Fiscal Policy under Balanced Budget and Indeterminacy: A New Keynesian Perspective*

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Abstract. We investigate the effect of fiscal policy on equilibrium determinacy in a New Keynesian economy with rule-of-thumb (liquidity-constrained) consumers and capital accumulation by focusing on the inter-action between monetary policy and taxation under the assumption of balanced budget. Our main finding is that taxation of firms' monopoly rents enforce the Taylor principle – the prescription that the nominal interest rate must respond more than one for a unitary change in inflation – as a criterion for equilibrium determinacy.

Keywords: Rule-of-thumb consumers, equilibrium determinacy, fiscal and monetary policy inter-actions, tax distortions, balanced government budget.

JEL codes: E61, E63.

1. INTRODUCTION

There is a large literature on tax distortions, balanced budget rules and equilibrium indeterminacy suggesting that policy feedback rules linking monetary and fiscal instruments to the state of the economy can induce endogenous fluctuations and hence are destabilizing.[1] King *et al*. (1988), e.g., show that in a real business cycle model the amplitude of the cycle increases when the government follows a balanced-budget rule and finances its spending with income taxes. In an important contribution, Schmitt-Grohè and Uribe (1997) prove that expectations of future higher

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[1] See, among other, King *et al*. (1988), Leeper (1991), Woodford (1994), Sims (1994), Schmitt-Grohè and Uribe (1997 and 2000), Leith and Wren-Lewis (2000), Gali *et al*. (2004), Guo and Harrison (2004).

tax rates can be self-fulfilled when income taxation is endogenously determined in order to balance the budget whereas the growth rate of government expenditure is exogenously fixed.

Guo and Harrison (2004) illustrate that Schmitt-Grohé and Uribe's indeterminacy result crucially depends on a fiscal policy where the tax rate decreases with the household's taxable income, i.e. constant government expenditures financed by proportional taxation on income. Specifically, they modify Schmitt-Grohé and Uribe's analysis by allowing for endogenous public spending and transfers financed by separate fixed tax rates, a different balanced-budget rule that is commonly used in the real business cycle literature. Under their formulation, the economy does not display endogenous business cycles driven by agents' animal spirits.

Following the Guo and Harrison's formulation, we develop a New-Keynesian (NEK) DSGE model with distortionary fiscal policy and rule-of-thumb behavior, as introduced by Galì *et al.* (2004, 2007). The key question of the paper is whether fiscal policy construction alters the scope for the equilibrium of the economy to be indeterminate. In the wake of the equilibrium analysis we show how tax policy is conducive to enforce the Taylor principle – the prescription that the nominal interest rate must respond more than one for one change in inflation – as a criterion for equilibrium determinacy.

Our starting point is the paper by Galì *et al.* (2004), who find that a presence of a significant proportion of households who do not participate in the financial market affects the conditions under which a standard Taylor rule delivers the uniqueness of the rational expectation equilibrium.[2] In a nutshell, as the standard interest rate effect operates only through a small proportion of unrestricted consumers, an expected increase in the economic activity and inflation

[2] In addition to Gali *et al*. (2003, 2004), the effects of rule-of-thumb consumers on monetary policy have been studied, among others, also by Amato and Laubach (2003), Colciago (2007), Di Bartolomeo and Rossi (2007), Rossi (2007) and Bilbiie (2008), Horvath (2009). For applications of this assumption to the Ricardian equivalence and fiscal policy see Mankiw (2000) and references therein.

also bumps up real wages and thus the consumption of restricted consumers. In order to bring inflation under control and rule out self-fulfilling prophecies the reaction of the real interest rate must be stronger than in the canonical NEK model (i.e., without the presence of restricted consumers). As a consequence, a more aggressive monetary policy would be necessary to stabilize the economy.

We investigate the Galì *et al.* (2004)'s result by focusing on the interaction among fiscal and monetary policies. We argue that the above described theoretical mechanism, triggered by an increase in real wages and a slump in markups, is sensitive to the presence of fiscal authorities and it is not invariant to the way public expenditure is financed. We find that a crucial role is performed by a fixed corporate tax rate and an endogenous public spending. Once the corporate taxation is introduced, fiscal policies based on balanced-budget rule may stabilize the economy differently from the common wisdom.

The intuition behind our main result can be illustrated by an example. An unexpected increase on consumption triggers an inflationary pressure, a rise in real wages and a decline in firms' markups due to price stickiness. Therefore, in our framework lower markups mean lower revenues from corporate taxation. Hence, to the extent that fiscal policy follows a balanced-budget rule, government cuts expenditure and reduces aggregate demand. This effect tends to compensate the adverse impact of rule-of-thumb consumption on stability as it goes in the opposite direction.

We compare different sources of distortionary taxation by also considering income taxation and social security contributions. These, however, do not have stabilizing effects as they do not counter-balance the output expansion driven by animal spirits. Only corporate taxation reduces tax revenues and, hence, aggregate demand. Thereby, we only partially confirm the Guo and Harrison's result in a New Keynesian framework, in the sense that it only holds for corporate taxation.

Our results are related to recent streams of literature that investigate the interactions between fiscal and monetary policy and introduce rule-of-thumb consumers in DSGE models. Indeed, the literature exhibits a remarkable asymmetry with respect to the analysis of monetary and fiscal instruments to stabilize the economy. The analysis of monetary policy rules is widespread and detailed; the same is not true for fiscal rules. This is more likely due to the fact that if monetary dynamics are determinate there is no active role for fiscal policy (see Leeper, 1991; Leith and von Thadden, 2008). As emphasized in Leith and von Thadden (2008) an environment that departs from Ricardian equivalence modifies this logic implying that equilibrium dynamics are driven by an interaction among fiscal and monetary policies. Our contribution widely shares this setting.

Compared to the recent literature on rule-of-thumb consumers in New Keynesian DSGE models, our findings uphold the stabilizing role of distortionary taxation by taking into account a new point of view. Colciago (2007) in fact emphasizes the stabilizing effects of distortionary income taxation by considering exogenous public spending *à la* Schmitt-Grohè and Uribe (1997),[3] we instead analyze balanced-budget rules and macroeconomic stability by considering the alternative approach of Guo and Harrison (2004). Our paper illustrates that Galì *et al.* (2007)'s key analytical finding[4] crucially depends on the assumption of an exogenous public spending financed by lump-sum taxes. We show that indeterminacy disappears if the government finances endogenous public spending with a fixed corporate tax rate. Therefore, in this case, for very plausible values of corporate tax rate, the New Keynesian framework augmented with rule-of-thumb consumers does not exhibit multiple equilibria driven by agents' animal spirits.

It is also worth mentioning that our result could strongly affect the main analytical conclusions about passive monetary rule – i.e. a timid reaction of the central bank to inflation pressure –

[3] See also Rossi (2007) and Horvath (2009).

[4] The empirical finding of a crowding in of government expenditure on private consumption is not investigated in our paper. However, it could be developed in further studies.

carried forward by, e.g., Bilbiie (2008) and Di Bartolomeo and Rossi (2007). More in details, according to these authors the presence of restricted consumers may invert the slope of the IS curve; in this case a passive monetary policy is stabilizing.[5] According to this view, Bilbiie (2008) explains the conduct of monetary policy in the *pre-Volcker period*. Our findings implicitly challenge the robustness of theoretical results about the effects of passive monetary policies with an inverted IS curve. In fact, we show that, when the model properly incorporates a very simple tax design, a standard Taylor rule is still able to prevent equilibrium indeterminacy as it is sustained by the fiscal policy.

The remainder of the paper is structured as follows. Next section describes the basic framework. Section 3 derives the model dynamics around the steady state. Section 4 investigates the model properties. A final section concludes.

2. THE MODEL

We consider a *continuum* of households distributed in a unitary segment of mass one. Households can be of two different kinds: a fraction of them $(1-\lambda)$ can access to the capital markets, whereas the remaining proportion (λ) cannot and thus has to consume all the current disposable income.[6] We refer to the former as *optimizing* or *Ricardian* households and to the latter as *rule-of-thumb* or *non-Ricardian* households.

The period utility function is common across households and it has the following form

[5] More precisely, if the share of rule of thumb consumers is high enough a sufficient condition to avoid indeterminacy requires either a relatively loose policy or a stronger reaction to inflation (See also Di Bartolomeo and Rossi 2007).

[6] Spenders' behavior can be interpreted in various ways, e.g. different interpretations include myopia, limited participation to asset markets or fear of saving. See Mankiw (2000) and references therein. Some evidence of the quantitative importance of rule-of-thumb consumers is provided by Campbell and Mankiw (1989), Jappelli (1990), Shea (1995), Parker (1999), Souleles (1999), Fuhrer (2000), Fuhrer and Rudebusch (2004), Ahmad (2005), Di Bartolomeo *et al*. (2009).

(1) $$U_t(i) = \frac{1}{1-\sigma}\left[C_t(i)\left(L_t(i)\right)^{\nu}\right]^{1-\sigma} \quad i \in [0,1]$$

where $C_t(i)$ is agent *i*'s consumption and $L_t(i)$ is leisure. Available time is normalized to unity so that $L_t(i) + N_t(i) = 1$, where $N_t(i)$ denotes hours worked. Consumption and labor are not separable in the period utility, where $\sigma \geq 0$ is the inverse of the elasticity of inter-temporal substitution of an aggregate factor composed by consumption and leisure, while $\nu > 0$ denotes a cost of working.

Optimizer households can access to capital markets to save and smooth consumption over time. Their preferences are thus defined by the discount factor $\beta \in (0,1)$ and equation (1). The Ricardian household chooses consumption, leisure, investment and bonds and maximizes (1) taking account of a sequence of budget constraints and a capital accumulation equation, taking as exogenously given public expenditure.

The budget constraint faced by the Ricardian household is

(2) $$P_t\left(C_t^o + I_t\right) + B_t = \left(W_t N_t^o + R_t^K K_{t-1} + D_t\right)\left(1-\tau_Y\right) + B_{t-1}R_{t-1}$$

where R_t^K is the nominal return on capital, K_t the capital, I_t the investment, D_t the dividends from ownership of firms and B_t the quantity of nominally risk-less bonds purchased in period *t*, maturing in period $t+1$; each bond pays R_{t+1} of money at maturity (hence R_t is the nominal interest rate);[7] τ^Y denotes the income tax rate. Variables relative to Ricardian agents are denoted with the superscript "o".[8]

The capital accumulation equation is

[7] In addition to the budget constraint, we assume that the Ricardian representative household is also constrained by a standard solvency equation that prevents it from engaging in Ponzi-type schemes. Recall that non-Ricardian households do not save; thus they do not face any solvency condition.

[8] It is worth noticing that we omitted the index "i" for individual households and index "o" for capital, investment, dividends and bonds as only Ricardian consumers hold firms and buy bonds.

(3) $$K_t = (1-\delta)K_{t-1} + \phi\left(\frac{I_t}{K_{t-1}}\right)K_{t-1}$$

where $\phi\left(\frac{I_t}{K_{t-1}}\right)K_{t-1}$ represents the capital adjustment costs, which determines the change in the capital stock (gross of depreciation) induced by investment spending I_t. We assume $\phi'(.) > 0$, $\phi''(.) \le 0$, $\phi'(\delta) = 1$ and $\phi(\delta) = \delta$. The function of the adjustment costs is convex and the corresponding value of the equilibrium level of the ratio investment-to-capital stock is equal to the depreciation rate, i.e. in the steady state there are not adjustment costs.

By computing and rearranging the first-order conditions, one obtains

(4) $$(1-\tau_Y)\frac{W_t}{P_t} = \nu\frac{C_t^o}{L_t^o}$$

(5) $$E_t\left[\frac{C_t^o}{C_{t+1}^o}\right]^{\sigma}\left[\frac{L_{t+1}^o}{L_t^o}\right]^{\nu(1-\sigma)} = \frac{1}{\beta R_t}E_t\left[\frac{P_{t+1}}{P_t}\right]$$

(6) $$P_t Q_t = \frac{1}{R_t}\left\{(1-\tau^Y)E_t R_{t+1}^K + E_t P_{t+1} Q_{t+1}\left[(1-\delta) + \phi_{t+1} - \left(\frac{I_{t+1}}{K_t}\right)\phi'_{t+1}\right]\right\}$$

where $Q_t = \partial I_t / \partial K_t = \left[\phi'(\partial I_t / \partial K_{t-1})\right]^{-1}$ is the Tobin's Q or the real shadow value of capital. Equation (4) is the intra-temporal optimality condition setting the marginal rate of substitution between leisure and consumption equal to the real net wage; equation (5) is the Euler condition for the optimal inter-temporal allocation of consumption; equation (6) is the inter-temporal path of the Tobin's *Q*.

Non Ricardian households cannot borrow or save. Each period rule-of-thumb consumers thus solve a static maximization problem. Formally, they choose the labor and consumption path that maximize (1) subject to the constraint that all their labor income is consumed:

(7) $$P_t C_t^r = W_t N_t^r (1-\tau_Y)$$

The first order condition is:

(8) $$\left(1-\tau_Y\right)\frac{W_t}{P_t}=\nu\frac{C_t^r}{L_t^r}$$

Which, combined with the budget constraint, can be rewritten as:

(9) $$C_t^r=\frac{W_t}{P_t}N_t^r\left(1-\tau_Y\right)$$

By using $L_t^r=1-N_t^r$, we obtain a constant amount of labor supplied by rule-of-thumb consumers:

(10) $$N_t^r=\frac{1}{1+\nu}=N^r$$

The consumption of the Non Ricardian household is thus a proportion of the real wage

(11) $$C_t^r=\frac{W_t}{P_t}\frac{1}{1+\nu}\left(1-\tau_Y\right)$$

The aggregate expressions for consumption and labor are simply the weighted average of the single consumer type variables:

(12) $$C_t=\left(1-\lambda\right)C_t^o+\lambda C_t^r$$

(13) $$N_t=\left(1-\lambda\right)N_t^o+\lambda N_t^r$$

By substituting the constant employment for the rule-of-thumb households, we derive

(14) $$N_t=\left(1-\lambda\right)N_t^o+\frac{\lambda}{1+\nu}$$

The aggregate first order condition is:

(15) $$C_t=\frac{1}{\nu}\left(1-\tau_Y\right)\frac{W_t}{P_t}\left(1-N_t\right)$$

Regarding the supply side, we consider an economy vertically differentiated composed by two sectors. The final sector is perfectly competitive, while in the intermediate good sector producers are monopolistic competitors.

More precisely, we assume a continuum of intermediate firms, uniformly distributed over the unit interval. Each firm produces a differentiated intermediate good that is combined in a competitive final sector, which uses a Dixit and Stiglitz technology. The final goods technology displays constant returns of scale and does not require labor or capital to produce a unit of the final good, but only intermediate commodities, i.e. $Y_{t,h}$. Formally,

(16) $$Y_t = \left(\int_0^1 \left(Y_{t,h} \right)^{\frac{\varepsilon-1}{\varepsilon}} dh \right)^{\frac{\varepsilon}{\varepsilon-1}}$$

Any final good firm will potentially make profits defined by

(17) $$\pi = P_t Y_t - \int P_{t,h} Y_{t,h} dh$$

Each firm sets a price at each period to maximize its profits by considering its production function. In formal terms, each firm maximizes equation (17) subject to (16). The assumption of free entry implies that profits will equal zero in equilibrium, the first order conditions for profit maximization lead to the following demand function:

(18) $$P_{t,h} = \left(\frac{Y_{t,h}}{Y_t} \right)^{-\frac{1}{\varepsilon}} P_t$$

We capture the degree of monopoly power of each firm by the gross markup $\left(\varepsilon - 1\right)\varepsilon^{-1}$, where $\varepsilon > 1$.

The production function for a typical intermediate goods firm is given by:

(19) $$Y_{t,h} = K_{t-1,h}^{\alpha} N_{t,h}^{1-\alpha}$$

where $N_{t,h}$ and $K_{t,h}$ represent the labor services and the capital, and α the capital share. Profit maximization, taking the wage and the rental cost as given, is

(20) $$\text{Max } \Pi_{t,h} = \left[P_{t,h} Y_{t,h} - \left(1 + \tau_N\right) W_t N_{t,h} - R_t^K K_{t-1,h} \right] \left(1 - \tau_\Pi\right)$$

subject to (18) and equation (19), where τ^N is the labor tax rate[9] and τ^Π the corporate tax rate paid by firms and exogenously taken.

The solution of the above problem implies the following first order conditions:

(21) $$\frac{R_t^K}{P_{t,h}} = \frac{\varepsilon - 1}{\varepsilon} \alpha \frac{Y_{t,h}}{K_{t-1,h}}$$

[9] It can be also interpreted as employers' social security contributions.

(22) $$\left(1+\tau_N\right)\frac{W_t}{P_{t,h}}=\frac{\varepsilon-1}{\varepsilon}\left(1-\alpha\right)\frac{Y_{t,h}}{N_{t,h}}$$

The firm's first order conditions represent the input demand schedules.

For the sake of simplicity, we assume a symmetric equilibrium. We then impose $Y_{t,h}=Y_{t,k}=Y_t$, $C_{t,h}=C_{t,k}=C_t$, $I_{t.h}=I_{t.k}=I_t$, $N_{t,h}=N_{t,k}=N_t$ for all j and $k\in\left[0,1\right]$.

Intermediate firms set nominal prices as in Calvo (1983). Each firm resets its price with probability $\left(1-\omega\right)$ each period, while the remaining fraction ω of producers keep their prices unchanged.

A firm resetting its price in period t seeks to maximize

(23) $$\underset{\{P_t^*\}}{\text{Max}}\; E_t\sum_{i=0}^{\infty}\omega^i\left[\Lambda_{t,t+i}Y_{t+i,h}\left(P_t^*-P_{t+i}MC_{t+i}\right)\right]$$

subject to $Y_{t+k,h}=\left(P_t^*\right)^{-\varepsilon}P_{t,h}^{\varepsilon}Y_{t+k}$, where $\Lambda_{t,t+i}$ is the discount factor, P_t^* represents the price chosen by firms resetting prices at time t and MC_t the marginal cost at time t.

The first order condition for this problem is:

(24) $$\sum_{i=0}^{\infty}\omega^i E_t\left[\Lambda_{t,t+i}Y_{t+i,h}\left(P_t^*-\frac{\varepsilon}{\varepsilon-1}P_{t+i}MC_{t+i}\right)\right]=0$$

Finally, the equation describing the dynamics for the aggregate price level is given by:

(25) $$P_t=\left[\omega P_{t-1}^{1-\varepsilon}+\left(1-\omega\right)\left(P_t^*\right)^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}}$$

where P_t^* is the optimal price chosen by firms resetting at time t.

We assume that a central bank set the growth of interest rate according to a standard Taylor rule, which satisfies the Taylor principle, i.e. the nominal interest rate reacts more than one to the expected inflation.[10] Formally,

[10] It is worth noticing that this rule always implies determinacy in the canonical model. See among other Woodford (2004).

(26) $$R_t = \left(\frac{P_{t+1}}{P_t}\right)^{\theta_\pi} + Y_t^{\theta_y}$$

where $\theta_\pi > 1$.

Government finances public expenditure (G_t) only by taxation. The government spending is thus endogenously determined every period by balancing, in expected term, the following budget constraint:

(27) $$G_t = \tau_Y\left(\frac{W_t}{P_t}N_t + \frac{R_t^K}{P_t}K_{t-1} + \frac{D_t}{P_t}\right) + \frac{\tau_\Pi}{1-\tau_\Pi}\frac{D_t}{P_t} + \tau_N\frac{W_t}{P_t}N_{t,h}$$

After aggregation, a standard aggregate resource constraint also holds:

(28) $$Y_t = C_t + I_t + G_t$$

3. DYNAMICS AROUND THE STEADY STATE

In the long run our economy progresses to a zero-debt and a zero-inflation steady state, where, for the sake of simplicity, we also assume $P=1$. The budget constraint for the optimizers becomes $C^o + I = \left(WN^o + R^K K + D\right)\left(1-\tau_Y\right)$. The steady state for investment, discount factor, marginal utility of wealth, Tobin's Q are respectively: $\delta K = I$, $\beta R = 1$, $\left[C^o\left(L^o\right)^\nu\right]^{-\sigma} L^{o\nu} = \Lambda$ and $Q = 1$.

By using the optimality conditions, we can derive the unique steady state for consumption of Ricardian households and capital rental cost as a function of the coefficient of time preference ρ (which is equal to r in the long run):

(29) $$\left(1-\tau_Y\right)W = \nu\frac{C^o}{1-N^o}$$

(30) $$\left(1-\tau_Y\right)R^K = \frac{1}{\beta} - \left(1-\delta\right) = \rho + \delta$$

The same is true for the rule-of-thumb consumers:

(31) $$C^r = WN^r\left(1-\tau_Y\right) = \frac{W}{1+\nu}\left(1-\tau_Y\right)$$

The steady-state analysis for the intermediate firms yields $Y = K^{\alpha}N^{1-\alpha}$, $R^K = MC\alpha YK^{-1}$, $\left(1+\tau_N\right)W = MC\left(1-\alpha\right)YN^{-1}$ and $P = P^* = 1 = \mu MC$, where $MC = \left(\varepsilon-1\right)\varepsilon^{-1}$ is the marginal cost and $\mu = \varepsilon\left(\varepsilon-1\right)^{-1}$ is the mark-up. It follows that:

(32) $$\frac{R^K K}{Y} = MC\alpha = \frac{\alpha}{\mu}$$

(33) $$\frac{WN}{Y} = MC\frac{1-\alpha}{1+\tau_N} = \frac{1-\alpha}{\mu\left(1+\tau_N\right)}$$

Government and aggregate resource constraints are in the long run equal to:

(34) $$G = \tau_Y\left(WN + R^K K + D\right) + \frac{\tau_{\Pi}}{1-\tau_{\Pi}}D + \tau_N WN$$

(35) $$Y = C + I + G = \left(1+\tau_N\right)WN + R^K K + \frac{1}{1-\tau_{\Pi}}D = \left(MC\right)Y + \left(1-MC\right)Y$$

From equation (35) dividends are $D = \left(1-\tau_{\Pi}\right)\left[Y - \left(1+\tau_N\right)WN - R^K K\right] = \frac{\left(1-\tau_{\Pi}\right)Y}{\varepsilon}$, thus:

(36) $$\frac{D}{Y} = \frac{1-\tau_{\Pi}}{\varepsilon}$$

The share of public expenditure is

(37) $$s_g = \frac{1-\alpha}{\mu}\frac{\tau_Y + \tau_N}{1+\tau_N} + \frac{\tau_{\Pi}\left(1-\tau_Y\right) + \tau_Y\left[1+\left(\varepsilon-1\right)\alpha\right]}{\varepsilon}$$

By combining equations (30) and (32), we obtain the share of investment:

(38) $$s_i = \frac{\alpha\delta\left(1-\tau_Y\right)}{\left(\rho+\delta\right)}\frac{\varepsilon-1}{\varepsilon}$$

The share of consumption is easily determined from $s_c = 1 - s_i - s_g$:

(39) $$s_c = 1 - s_g - \frac{\alpha\delta\left(1-\tau_Y\right)}{\mu\left(\rho+\delta\right)}$$

After some tedious algebra, we obtain the steady state level of aggregate employment:

(40) $$N=\frac{(1-\alpha)(\rho+\delta)(1-\tau_Y)}{\nu\left[(\rho+\delta)(1-s_g)(1+\tau_N)\mu-\alpha\delta(1-\tau_Y)(1+\tau_N)\right]+(1-\alpha)(\rho+\delta)(1-\tau_Y)}$$

We can rewrite the level of employment, consumption, and Ricardian consumption as: $N=(1-\lambda)N^o+\lambda(1+\nu)^{-1}$, $C=\nu^{-1}W(1-N)(1-\tau^Y)$, $C^o=W(1+\nu)^{-1}(1-\tau_Y)$ and, by combining these aggregate equations, it is possible to obtain the consumption steady state ratios; by using $1=(1-\lambda)\gamma_o+\lambda\gamma_r$, it follows that $\gamma_o=\frac{C^o}{C}=\frac{1-\lambda\gamma_r}{1-\lambda}$ and $\gamma_r=\frac{C^r}{C}=\frac{\nu}{1+\nu}\frac{1}{1-N}$.

Disregarding on tax rate, the resulting linear equations of the firm's optimality conditions are:

(41) $$y_t=\alpha k_{t-1}+(1-\alpha)n_t$$

(42) $$r_t^K-p_t=-\hat{\mu}_t+y_t-k_{t-1}$$

(43) $$w_t-p_t=-\hat{\mu}_t+y_t-n_t$$

(44) $$\pi_t=\beta E_t\pi_{t+1}-\frac{(1-\beta\omega)(1-\omega)}{\omega}\hat{\mu}_t$$

where $\hat{\mu}_t$ represents the (log)deviations of the gross markup from its steady-state level, which is equal to the inverse of the marginal cost, i.e. $\widehat{MC}_t=-\hat{\mu}_t$ in logs.

The log-linearization of the production function (16) and of the first order conditions ((21) and (22)) gives us the transition dynamic of the output (41) and the input demand schedules ((42) and (43)). The labor demand curve is downward sloping and depends negatively upon the labor taxation. The New Keynesian Phillips Curve is derived by solving the firm's maximization problem (23) in a standard manner.[11]

Regarding the household's optimization problem, the log-linearized version of the capital accumulation equation is:

(45) $$k_t=(1-\delta)k_{t-1}+\delta i_t$$

By rewriting the Ricardian leisure as a function of the aggregate employment (notice that

[11] See e.g. in Walsh (2003: Appendix 5.7.3).

$n_t = (1-\lambda)\gamma_o n_t^o$, then $l_t^o = -\frac{N}{(1-\gamma_o N)}\frac{1}{(1-\lambda)} n_t$ and $l_t = -\varphi n_t$, where $\varphi = \frac{N}{1-N}$ is the steady-state inverse Frisch labor supply elasticity), the optimal conditions for Ricardian and Non Ricardian consumers are then $w_t - p_t = c_t^r$, $w_t - p_t = c_t^o - \frac{N}{(1-\gamma_o N)(1-\lambda)} n_t$ $\quad c_t^o = E_t c_{t+1}^o - \frac{1}{\sigma}\left(r_t - E_t \pi_{t+1}\right) + \frac{(1-\sigma)\nu}{\sigma(1-\gamma_o N)(1-\lambda)} \Delta n_{t+1}$. The Euler equation is standard except for the presence of the deviations in employment. The presence of the deviations in employment is induced by the fact that the marginal utility of consumption in each period depends upon the leisure. If $\sigma < 1$, the marginal utility of consumption and leisure are positively related. An increase in current labor decreases the marginal utility of consumption and, ceteris paribus, current consumption must decrease.

The log-linearized version of the aggregate labor supply is:

(46) $$w_t - p_t = c_t + \varphi n_t$$

and log-linearized consumption is $c_t = (1-\lambda)\gamma_o c_t^o + \lambda \gamma_r c_t^r$. After some algebra we also obtain $c_t^r = c_t + \varphi n_t$ and $c_t^o = c_t - \frac{\nu(1+\nu)^{-1}\lambda\varphi(1+\varphi)}{1-\nu(1+\nu)^{-1}\lambda(1+\varphi)} n_t.$, the aggregate Euler Equation is thus:

(47) $$c_t = E_t c_{t+1} - \frac{1}{\sigma}\left(r_t - E_t \pi_{t+1}\right) - \nu\left[\frac{(\sigma-1)N}{\sigma(1-\gamma_o N)(1-\lambda)} + \frac{\lambda\varphi\gamma_r}{1-\lambda\gamma_r}\right]\Delta n_{t+1}$$

The log-linear equations describing the dynamics of Tobin's Q and its relationship with investments are:

(48) $$q_t = -\phi^{II}(\delta)\delta\left(i_t - k_{t-1}\right) = \frac{1}{\eta}\left(i_t - k_{t-1}\right)$$

(49) $$q_t = \beta E_t q_{t+1} + \left[1-\beta(1-\delta)\right]\left(r_{t+1}^k - p_{t+1}\right) - \left(r_t - E_t \pi_{t+1}\right)$$

where η represents the elasticity of the investment-capital ratio with respect to Q.

The log-linear equations describing the dynamics of government purchases, dividends and aggregate resources around zero-debt steady state are given by:

(50) $$s_g g_t = \frac{\tau_Y \alpha}{\mu}\left(r_t^k - p_t + k_{t-1}\right) + \frac{\tau_Y + \frac{\tau_\Pi}{1+\tau_\Pi}}{\varepsilon}\left(d_t - p_t\right) + \frac{\left(1-\alpha\right)\left(\tau_Y + \tau_N\right)}{\mu}\left(w_t - p_t + n_t\right)$$

where s_g is given by equation (37).

(51) $$d_t - p_t = y_t + \left(\varepsilon - 1\right)\hat{\mu}_t$$

(52) $$y_t = s_c c_t + s_i i_t + s_g g_t$$

The central bank sets the level of interest rate in such a way that a standard Taylor rule is followed:

(53) $$r_t = \theta_\pi \pi_t + \theta_y y_t$$

It is worth noticing that the targets of the above rule are consistent with the steady-state properties of the model.

We can now combine equilibrium conditions (41)-(53) to obtain a system of difference equations describing the log-linearized equilibrium dynamics of our economy. The system is composed of 13 equations and in 13 unknowns variables (y_t , k_t , n_t , $r_t^K - p_t$, $\hat{\mu}_t$, π_t , i_t , $w_t - p_t$, c_t , n_t , r_t , g_t , $d_t - p_t$).

4. CALIBRATION AND ANALYSIS OF EQUILIBRIUM PROPERTIES

4.1 Calibration

We investigate the stabilization properties of a Taylor rule when distortionary taxation is assumed. As we aim to compare our results to Galì *et al.* (2004 and 2007), which can be interpreted as a special case of our framework,[12] we calibrate the model to a quarterly frequency following Galì *et al.* (2004). We set the discount factor β equal to 0.99 (implying a steady state real annual return of

[12] More in details, Galì *et al.* (2004) can be obtained by assuming all the tax rates equal to zero. Condition for determinacy under lump-sum taxation introduced in Galì *et al.* (2007) does not differs from those described in Galì *et al.* (2004).

4%). We choose a baseline value of one for σ, which corresponds to a separable (log–log) utility specification and set v at 0.7, a value consistent with a *unit* Frisch elasticity of labor supply. The elasticity of output with respect to capital (α) is 1/3. The elasticity of substitution across intermediate goods (ε) is 6, a value consistent with a steady state markup of 20%. The fraction of firms that keep their prices unchanged (θ) is 0.75, which corresponds to an average price duration of one year. The rate of depreciation (δ) of capital is 0.025 (implying a 10% annual rate). Labor disutility is set to obtain an employment level of 1/2 in the steady state as Gali *et al*. (2004). We set the elasticity (η) of investment with respect to Tobin's Q equal to one. Monetary policy follows a standard Taylor rule.

Regarding fiscal policy, which is not included in Gali *et al*. (2004), we use the average tax rates for the US computed from OECD dataset.[13] It is worth noticing that our tax-rate parameterization implies a share of government expenditures about 0.2, as observed in most industrialized economies and often assumed in policy experiments.

Parameters are summarized in Table 1. We will later consider several deviations from our baseline to test the robustness of our findings.[14]

Table 1 – Baseline model calibration

Deep parameters	$\beta = 0.99$	$\varphi = 1$	$\sigma = 1$	$\eta = 1$
	$\alpha = 0.33$	$\varepsilon = 6$	$\delta = 0.025$	$v = 0.7$
Rule of thumb fraction	$\lambda = 0.67$			
Calvo's parameter	$\omega = 0.75$			
Monetary policy	$\theta_\pi = 1.5$	$\theta_y = 0.5$		
Tax rates	$\tau_\Pi = 0.35$	$\tau_N = 0.15$	$\tau_Y = 0.12$	

[13] Tax rates are computed from OECD tax database (www.oecd.org/ctp/taxdatabase). More details are available upon request from the authors.

[14] Further results about the sensitivity of our finding to changes in parameters are reported in a technical appendix available upon request from the authors.

4.2 Rule of thumb consumers and equilibrium determinacy

The model properties and the requirements for equilibrium determinacy underpin the dynamic behavior of aggregate variables in the short run analysis. Before stressing our results, it is useful to briefly discuss those of Galì *et al.* (2004).

Galì *et al.* (2004) find that the presence of rule-of-thumb consumers can dramatically change the properties of the interest rate set accordingly to a Taylor rule: monetary policies must be more aggressive with respect to inflation than in the traditional model to guarantee the determinacy. If monetary policy follows a Taylor rule, in fact, the combination between a high degree of price stickiness and a large share of rule-of-thumb consumers rules out the existence of a unique equilibrium converging to the steady state.

The rationale of Galì *et al.* (2004) can be understood by comparing the monetary policy behavior to stabilize the economy in the canonical case to that augmented with rule-of-thumb consumers. Considering, e.g., a non-fundamental shock of expectations in the demand curve, we can distinguish the two cases.

1. In the canonical model, the shock implies an increase in inflation, a fall in the real interest rate, and an increase in the output. Thus, it would be self-fulfilled. In order to avoid indeterminacy, the central bank has to react to inflation by increasing the nominal interest rate.
2. In Galì *et al.* (2004), the increase in economic activity and inflation also allows real wages to increase (see equation (44)) because of the decline in markups.[15] This generates an additional boom in consumption among non-Ricardian agents. Thus monetary policy must be more aggressive to avoid indeterminacy.

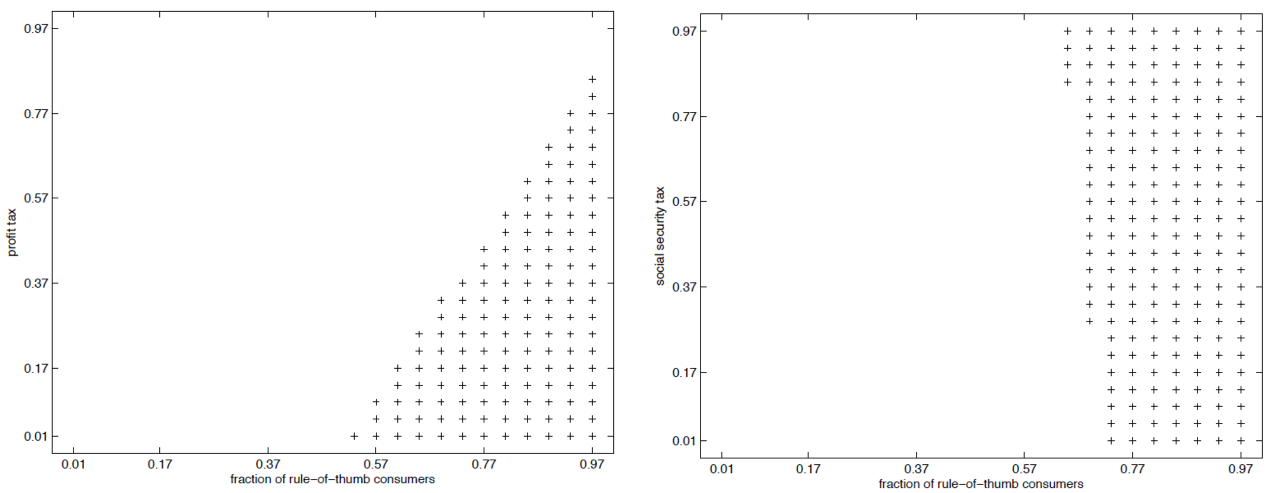
[15] It is worth noticing that, as Gali *et al*. (2004), we use a demand shock as example. It implies counter-cyclical markups. In a similar manner one can use a cost push shock or, instead, a technological shock that, however, implies different dynamics with pro-cyclical effects on markups.

4.3 Fiscal policy and equilibrium determinacy

In our model the indeterminacy mechanism described above may be contrasted by distortionary fiscal policies. We find that corporate taxation affects the conditions for indeterminacy in a substantial manner making sunspots less likely to be observed; by contrast, changes in the income and labor taxes have negligible or second order effects on equilibrium determinacy.

Our results are summarized in figure 1, which describes the indeterminacy regions (marked areas) as a function of the size of rule-of thumb consumers and different tax rates, when monetary policy is set according to a standard Taylor rule.[16]

Figure 1 – Regions of indeterminacy and tax rates



(a) (b)

Panel (a) shows that high rates of corporate tax restore determinacy also in presence of high fractions of rule-of-thumb consumers. By contrast social security contributions have an adverse

[16] The effects on determinacy of the income tax rate are not reported since they are of second order. Changes in the income tax do not affect determinacy. Results are available upon request.

but quite negligible effect on determinacy.

Table 2 focuses on the corporate tax and describes the combination of inflation coefficients and tax rates that assure determinacy in presence of different fractions of rule-of-thumb consumers. More in details, the first column reports the fraction of rule-of-thumb consumers; the second one describes the lowest inflation coefficient of the Taylor rule that assures equilibrium determinacy when the tax rate is zero (i.e. the case of Galì *et al.*, 2004); the last column reports the lowest corporate tax rate that assures determinacy if monetary policy is set according to a standard Taylor rule (i.e. $\theta_\pi = 1.5$ and $\theta_y = 0.5$).

Table 2 - Rule of thumb consumers, threshold inflation coefficient and threshold corporate tax rate

λ	θ_π	τ_π
Below 0.6	0.94 (Taylor Principle)	0.00
0.7	3.70	0.07
0.8	12.20	0.26
0.9	24.40	0.44

The first row describes the standard textbook case: if there are not rule-of-thumb consumers, the Taylor principle is sufficient to assure determinacy.[17]

By increasing the number of rule-of-thumb consumers, aggressive monetary policies are requested if there is no corporate taxation, e.g. a coefficient of 12.20 if the fraction of non Ricardian agents is 0.8 (as assumed by Gali *et al*., 2004). Alternatively, including fiscal policy into the picture, the Taylor rule guarantees stability if associated with an appropriate corporate tax rate, e.g., 0.26% if the fraction of non Ricardian agents is 0.8.

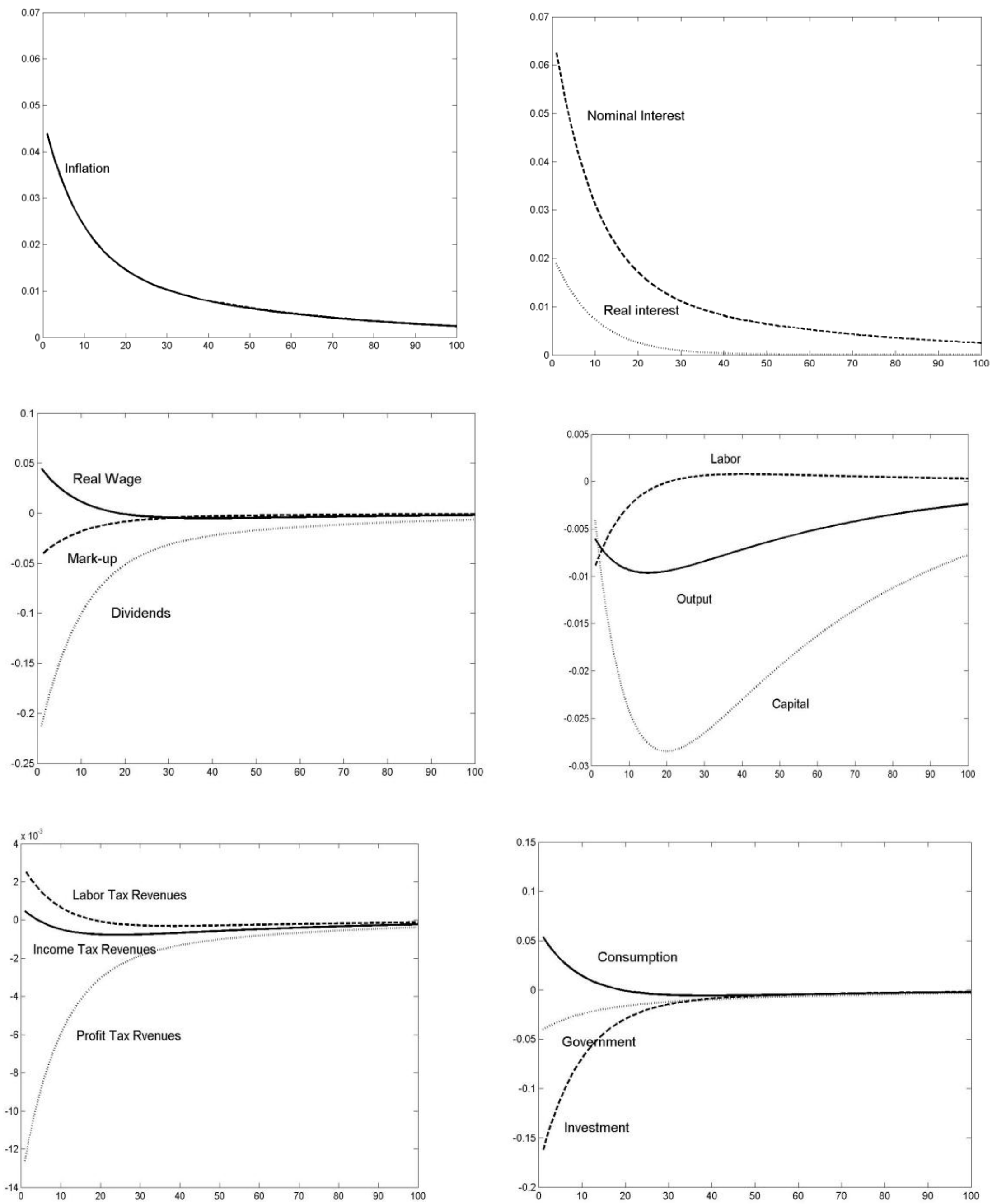
The rationale of our result can be understood by reconsidering the effects of a shock in economic

[17] Note that the coefficient on output of the Taylor rule is positive, thus the Taylor principle is satisfied for an inflation coefficient smaller than one.

activity, described in the previous section. An expectation-driven increase in activity gives a rise in real wages and a decline in firm markups due to price stickiness. Lower markups mean lower revenues from corporate taxation, because tax rates are kept constant. Hence, in order to balance the budget, government cuts expenditures that in itself reduce aggregate demand. This effect tends to stabilize the economy and thus call for a less aggressive response to inflation.

The dynamics of the demand shock is described in figure 2.

Figure 2 – Dynamic response to a positive shock in consumption



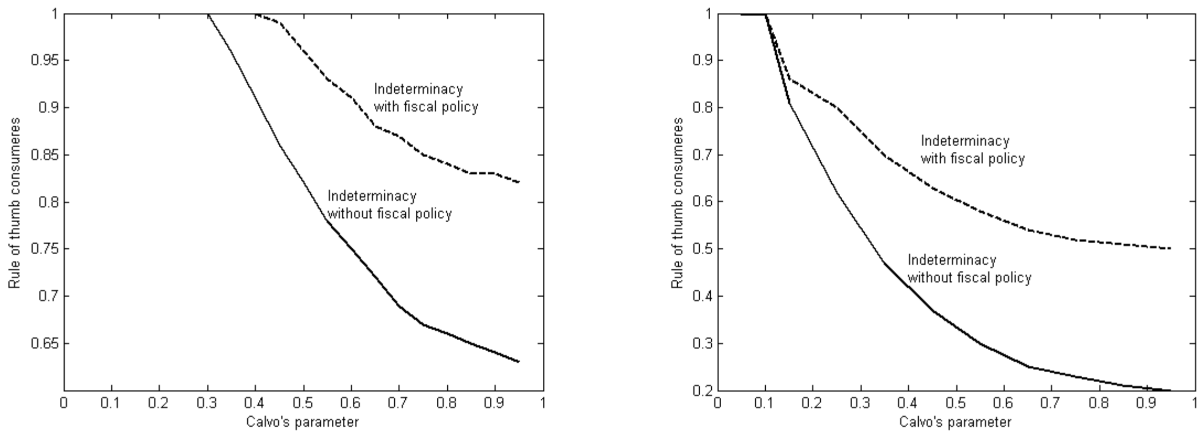
The output expansion is ruled out by the reduction of the aggregate demand due to both the increase in the real interest rate and the effect of corporate taxation. Real interest rate moderates consumption spending of financially unrestricted consumers and reduces private investment; fixed-corporate taxation and balanced-budget rule reduce tax revenues and government expenditures.

4.4 Robustness

As noticed by Galì *et al.* (2004), determinacy requirements are strongly affected by the relative risk aversion and degree of stickiness. We thus provide some robustness tests for our results by checking the effects of the interaction between fiscal policy and other key parameters.

The robustness with respect to risk aversion and price stickiness is described by figure 3. The figure shows the change of the regions of indeterminacy when fiscal policy is considered for different degrees of price stickiness and two different values of risk aversion ($\sigma = 1$ in panel (a) and $\sigma = 5$ in panel (b)).

Figure 3 – Regions of indeterminacy

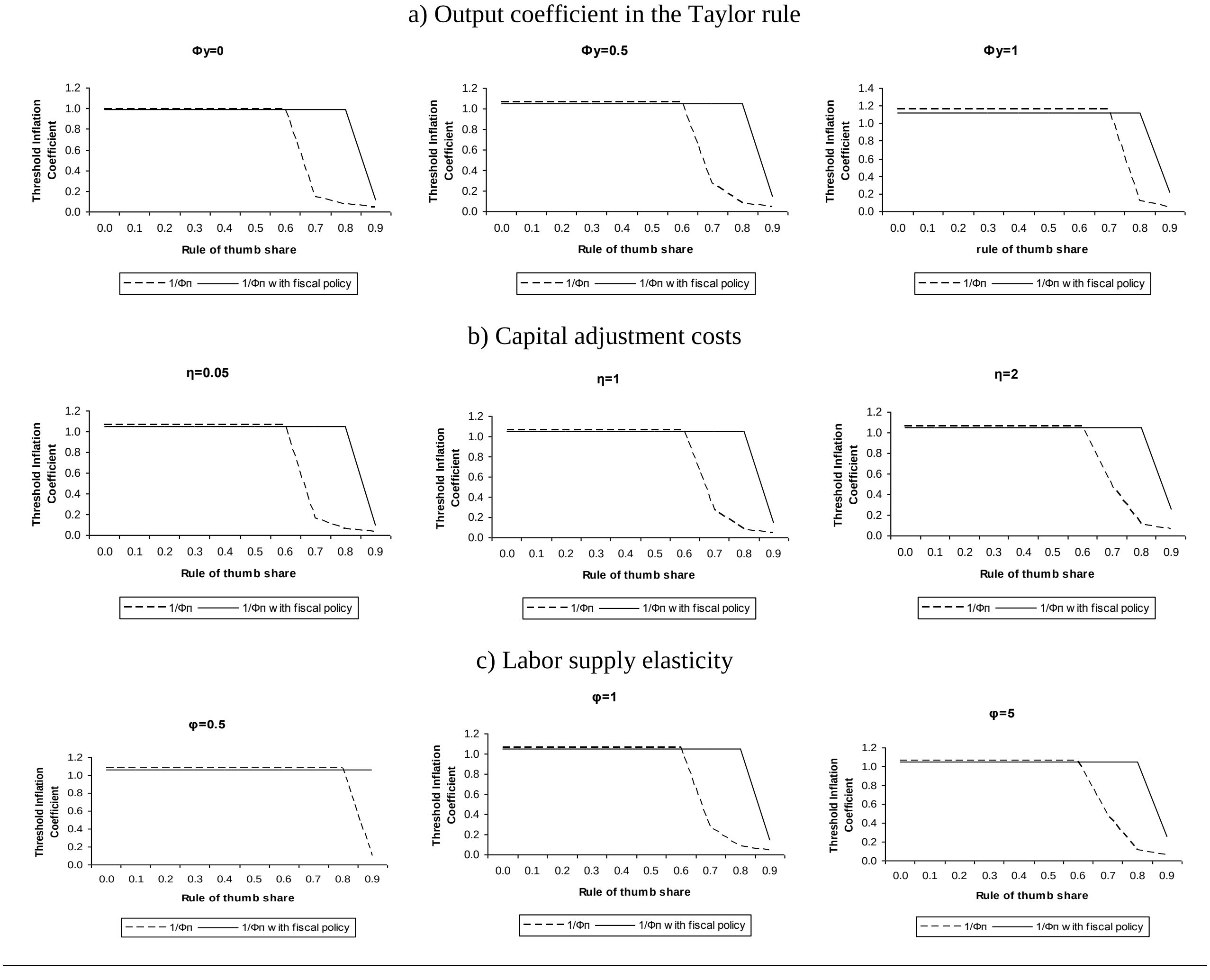


(a) $\sigma = 1$ (b) $\sigma = 5$

The effect of stickiness and risk aversion on indeterminacy described in Gali *et al*. (2004) are evident: higher degrees of stickiness and risk aversion increase the indeterminacy region. By contrast, fiscal policy always has a relevant stabilization effect.

In figure 4, we consider the sensitivity of our results by considering deviations from the baseline calibration with respect to changes in a) the output coefficient in the Taylor rule; b) capital adjustment costs; c) labor supply elasticity.

Figure 4 – Sensitivity analysis on output coefficient, capital adjustment cost, labor elasticity



Dotted lines represent the case without fiscal policy, whereas the continuous lines define stability regions when corporate taxes are introduced. The figure confirms our results in all cases.

5. CONCLUDING REMARKS

This paper analyzes the effects of monetary and fiscal rules with respect to the equilibrium determinacy in a New Keynesian DSGE model augmented with rule-of-thumb consumers.

Our main contribution is to show that a balanced budget rule may actually reduce the scope for indeterminacy when monetary policy is set according to a canonical Taylor rule.

In a nutshell, in our extension of Galì *et al.* (2004), a balanced budget rule financed by a fixed corporate tax rate implies that sunspot-driven fluctuations are less likely to be observed. This occurs because corporate taxation behaves as a substitute for monetary policy: endogenous public expenditure financed by corporate taxation varies in the same direction of the monetary policy that stabilize the economy. It follows that when corporate taxation is present, a less aggressive monetary policy is sufficient for stabilizing the economy. Thus, the findings of Galì *et al.* (2004), who instead call for more aggressive monetary policies, are not indifferent to fiscal policy structure.

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