Do tax distortions lead to more indeterminacy? A New Keynesian perspective

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May 2007

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FACULTY OF COMMUNICATION

Department of Communication, Working Paper No. 13 – 2007

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Abstract. Following the recent developments of the literature on stabilization policies, this paper investigates the effect of tax distortions on equilibrium determinacy in a New Keynesian economy with rule-of-thumb consumers and capital accumulation. In particular, we focus on the inter-action between monetary policy and tax distortions in supporting the saddle-path equilibrium under the assumptions of balanced budget and monetary policy satisfying a Taylor rule.

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

JEL codes: E61, E63.

1. Introduction

The Taylor principle is generally viewed as a criterion in the assessment of a monetary policy. An interest rate rule that satisfies this principle is viewed as a policy with stabilizing properties; by contrast the failure to meet the Taylor criterion is often associated with instability, i.e. equilibrium indeterminacy.[1] In a recent paper, Galì *et al*. (2003) have challenged this statement. By introducing rule-of-thumb consumers, who consume their current income as opposed to their permanent income, in a standard dynamic New Keynesian sticky price model, Jordi Galì and his coauthors show that this changes dramatically the properties of standard interest rate rules. In a canonical New Keynesian model, the presence of rule-of-thumb can be a possible source of indeterminacy capable to generate sunspot-led aggregate fluctuations even though the interest rate rule satisfies the Taylor principle, since it may no longer assure equilibrium uniqueness.

The argument of rule-of-thumb consumers, underlined by Galì *et al*. (2003), is further developed by other studies. The same authors expand it to fiscal policy; Galì *et al*. (2004) show how the interaction of the rule-of-thumb consumers with sticky prices and deficit financing can account for the existing evidence on the effect of government spending shocks on consumption, which else cannot be easily reconciled with existing optimizing business cycle models. Models in the real business cycle tradition often predict relatively low government spending multipliers, as a consequence of crowding-out effects on consumption. Nevertheless, the introduction of rule-of-thumb consumers combined with deficit financing can raise that multiplier dramatically.

Amato and Laubach (2003) explore the optimal monetary rule with rule-of thumb households and firms. By modeling consumers' rule-of-thumb behavior as a consumption habit, households' decisions today mimic past behavior of all agents, including optimizing agents. Amato and Laubach (2003) show that, while the monetary policy implications of rule-of-thumb firms are minimal, the interest rate is more sensitive to the presence of rule-of-thumb consumers; as their fraction increases higher inertial monetary policy is required.

Bilbiie (2004) also considers optimal monetary policy and shows that, in presence of rule-of-thumb consumers, a passive interest rate rule (i.e. a rule that does not satisfy the Taylor principle) is consistent with a welfare-maximization. Bilbiie (2004) tackles the point from both a theoretical and empirical point of view. Bilbiie (2004) shows how rule-of-thumb consumer can explain the puzzle of monetary policy before and after the Volker. In fact, monetary policy can leads to determinacy even if the Taylor rule is not satisfied when enough agents do not participate in asset markets. By

[1] See Woodford (2004) for a discussion.

assuming zero long-run profit due to transfer between rule-of-thumb consumers and savers[2] and an *ad hoc* lag scheme in the IS curve, Bilbiie (2004) provides some empirical support to his hypothesis.

Di Bartolomeo and Rossi (2006) investigate the effectiveness of monetary policy. By using a New Keynesian DSGE model, they find that monetary policy becomes more effective as the number of rule-of-thumb consumers increases. As usual, a change in the interest rate affect the trade-off between consumption today and consumption tomorrow, but, in limited asset market participation economies, the change in demand also stimulates the revision of the consumption plan of rule-of-thumb consumers. After a change in the interest rate, both spenders and savers revise their consumption plans in the same direction since reductions in the interest rate supports falls in current output and labor supply of savers and thus in aggregate real wages. Thus, even if a lower fraction of savers reduces the impact of interest rate policies because fewer agents smooth their consumption, it can sustain the effectiveness of the monetary policy by the spenders' reaction.

Colciago (2006) studies the determinacy properties of a New Keynesian model augmented with rule-of-thumb consumers when labor markets are not competitive and wages are sticky.[3] He shows how wage stickiness implies that the Taylor Principle is a necessary condition for equilibrium determinacy and that a positive response of aggregate consumption to a government purchase shock is not a robust feature of the model. Crowding-in of consumption vanishes as wage stickiness dampens real wage fluctuations associated to government spending-induced variation in real activity.

This paper extends the framework of Galì *et al*. (2003, 2004) by focusing on the interaction between monetary and fiscal policy in supporting the saddle-path equilibrium. More in detail, we introduce fiscal policy based on tax distortions and balanced government budget in a New Keynesian economy with rule-of-thumb consumers and capital accumulation and show that results stressed by Galì *et al.* (2004) are not indifferent to fiscal policy structure. The introduction of fiscal policy, based on tax distortion and balanced budget, in fact, facilitates the Taylor criterion as cornerstone of determinacy and restricts the spaces of sunspot-driven fluctuations in the business cycle.

The rest 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.

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[2] This technical assumption is needed to obtain that the steady-state share of spenders' consumption equal to the one of savers so that it is independent of fraction of rule-of-thumb consumers.

[3] Wages are set according to a Calvo's lottery as in Erceg *at al*. (2000) or Schmitt-Grohe and Uribe (2004).

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,[4] whereas the remaining proportion (λ) cannot and thus has to consume all the current disposable income. We refer to them as *rule-of-thumb* or *non-Ricardian* households and to the former as *optimizing* or *Ricardian* households.

Each optimizing consumer is assumed to maximize an inter-temporal utility function given by:

(1) $$E_t \sum_{t=0}^{\infty} \beta^t \left[\frac{1}{1-\sigma} \left(C_t^o L_t^{o\nu} \right)^{1-\sigma} \right]$$

subject to the sequence of budget constraints,

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

and the capital accumulation equation

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

where C_t^o and L_t^o represent consumption and leisure for optimizing household (hence we use a "o" superscript) and β is the discount factor. The period utility take the Cobb-Douglas form inside a CRRA function, 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. N_t^o is the level of employment, where $L_t^o = 1 - N_t^o$; W_t denotes the nominal wage, R_t^K 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 one-period safe bonds carried over from period $t-1$; τ_t^Y denotes the tax rate on labor, capital income and dividends. Bonds pay a nominal interest rate R_t.

In equation (3), $\phi\left(\frac{I_t}{K_{t-1}}\right) K_{t-1}$ represents the capital adjustment costs, which determines the change in the capital stock (gross of depreciation) induced by investment spending I_t. We assume $\phi'(.) > 0$, $\phi''(.) \leq 0$, $\phi'(\delta) = 1$ and $\phi(\delta) = \delta$. The function of the adjustment costs is convex and the

[4] 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 (2003) and Ahmad (2004).

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.

The consumer selects consumption, leisure, investment and security by maximizing equation (1) subject to the constraints (2) and (3), in solving the inter-temporal optimization problem the tax rate and public expenditure are taken as exogenously given.

By computing and rearranging the first-order conditions, one obtains the intra-temporal optimality condition setting the marginal rate of substitution between leisure and consumption equal to the real net wage; the Euler condition for the optimal inter-temporal allocation of consumption; the inter-temporal path of the Tobin's Q. Notice that leisure is present in the Euler condition given our assumption of the form of the period utility function (which is not separable).

(4) $$\left(1-\tau_t^Y\right)\frac{W_t}{P_t}=\nu\frac{C_t^o}{L_t^o}$$

(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) $$P_tQ_t=\frac{1}{R_t}\left\{\left(1-E_t\tau_{t+1}^Y\right)E_tR_{t+1}^K+E_tP_{t+1}Q_{t+1}\left[\left(1-\delta\right)+\phi_{t+1}-\left(\frac{I_{t+1}}{K_t}\right)\phi_{t+1}^{'}\right]\right\}$$

where $Q_t=\partial I_t/\partial K_t=\left[\phi'\left(\partial I_t/\partial K_{t-1}\right)\right]^{-1}$ is the Tobin's Q or the real shadow value of capital.

As we have introduced before, we assume that a proportion λ of households follow a rule-of-thumb and do not borrow or save. We refer to them through the superscript "r." Each period rule-of-thumb consumers solve their maximization problem, i.e. to choose the labor and consumption path that maximize:

(7) $$E_t\sum_{t=0}^{\infty}\beta^t\left[\frac{1}{1-\sigma}\left(C_t^rL_t^{r\nu}\right)^{1-\sigma}\right]$$

subject to the constraint that all their labor income is consumed

(8) $$P_tC_t^r=W_tN_t^r\left(1-\tau_t^Y\right)$$

The associated first order condition is given by:

(9) $$\left(1-\tau_t^Y\right)\frac{W_t}{P_t}=\nu\frac{C_t^r}{L_t^r}$$

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

(10) $$C_t^r=\frac{W_t}{P_t}N_t^r\left(1-\tau_t^Y\right)$$

By remembering that $L_t^r = 1 - N_t^r$, we obtain a constant amount of labor for rule-of-thumb consumers

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

Thus, the consumption is a proportion of the real wage

(12) $$C_t^r = \frac{W_t}{P_t}\frac{1}{1+\nu}\left(1-\tau_t^Y\right)$$

Aggregate leisure can be rewritten in function of the employment $L_t = 1 - N_t$.

Then we can formally write the weighted average of the variables for each consumer type:

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

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

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

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

The aggregate first order condition is:

(16) $$C_t = \frac{1}{\nu}\left(1-\tau_t^Y\right)\frac{W_t}{P_t}\left(1-N_t\right)$$

Regarding the supply side, we consider an economy vertically differentiated composed by two sectors. The final sector is perfectly competitive, while the intermediate goods 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 $Y_{t,h}$. Formally,

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

Any final good firm will potentially make profits defined by

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

Each firm sets a price at each period to maximize its profits by considering its production function. Formally each firm maximizes equation (18) subject to (17). 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:

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

We capture the degree of monopoly power of each firm by $(\varepsilon-1)\varepsilon^{-1}$, when $(\varepsilon-1)\varepsilon^{-1}=1$, the technology collapses to a competitive model since the intermediate goods are perfect substitutes, the demand curve is perfectly elastic and none of intermediate producer will be able to exploit its power. Henceforth, we assume degree of monopoly power of each firm between zero and one, i.e. $\varepsilon > 1$.

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

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

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

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

subject to $P_{t,h} = \left(\frac{Y_{t,h}}{Y_t}\right)^{-\frac{1}{\varepsilon}}$ and equation (20),

where τ_t^N is the labor tax rate and τ_t^{Π} the corporate tax rate paid by firms and exogenously taken.

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

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

(23) $$\left(1+\tau_t^N\right)\frac{W_t}{P_{t,h}} = \frac{\varepsilon-1}{\varepsilon}(1-\alpha)\frac{Y_{t,h}}{N_{t,h}}$$

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

For the sake of tractability, we assume a symmetric equilibrium. In the discussion that follows 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 $k \in [0,1]$.

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

A firm resetting its price in period t will seek to maximize

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

subject to $Y_{t+k,h} = \left(P_t^*\right)^{-\varepsilon} P_{t,h}^{\varepsilon} Y_{t+k}$, where $\Lambda_{t+k} = R_t^{-1} E_t \left[P_{t+1}/P_t\right]$ 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:

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

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

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

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 in according to a standard Taylor rule (Taylor (1993)), in which the Taylor principle is satisfied since the nominal interest rate reacts more than one to the expected inflation, thus eliminating indeterminacy in the canonical model:

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

The Government spending is endogenously determined every period by balancing, in expected term, the following budget constraint:

(28) $$P_t G_t + B_{t-1} R_t = \tau_t^Y \left(W_t N_t + R_t^K K_{t-1} + D_t \right) + \frac{\tau_t^\Pi}{1 - \tau_t^\Pi} D_t + \tau_t^N W_t N_{t,h} + B_t$$

where G_t is the government purchases.

The following standard aggregate resource constraint must also holds:

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

that, of course, also includes investments and public expenditure.

3. Dynamics around the Steady State

We begin by computing the steady state then a linear representation in the percentage deviations around the steady state is obtained. Conditions for uniqueness or indeterminacy are investigated in the next section by numerical methods.

In the long run our economy progresses to a zero-debt and a zero-inflation steady state position in which all variables are constant through the time. For the sake of simplicity, we 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 of consumption for Ricardian households and capital rental cost in function of the coefficient of time preference ρ, equal to r in the long run:

$$\left(1-\tau^Y\right)W = \nu \frac{C^o}{1-N^o} \tag{30}$$

$$\left(1-\tau^Y\right)R^K = \frac{1}{\beta} - \left(1-\delta\right) = \rho + \delta \tag{31}$$

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

$$C^r = WN^r\left(1-\tau^Y\right) = \frac{W}{1+\nu}\left(1-\tau^Y\right) \tag{32}$$

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

$$\frac{R^K K}{Y} = MC\alpha = \frac{\alpha}{\mu} \tag{33}$$

$$\frac{WN}{Y} = MC\frac{1-\alpha}{1+\tau^N} = \frac{1-\alpha}{\mu\left(1+\tau^N\right)} \tag{34}$$

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

$$G = \tau^Y\left(WN + R^K K + D\right) + \frac{\tau^\Pi}{1-\tau^\Pi}D + \tau^N WN \tag{35}$$

$$Y = C + I + G = \left(1+\tau^N\right)WN + R^K K + \frac{1}{1-\tau^\Pi}D = \left(MC\right)Y + \left(1-MC\right)Y \tag{36}$$

From equation (36) dividends are $D = \left[Y - \left(1+\tau^N\right)WN - R^K K\right]\left(1-\tau^\Pi\right) = \left(1-\tau^\Pi\right)\varepsilon^{-1}Y$, thus:

$$\frac{D}{Y} = \frac{1-\tau^\Pi}{\varepsilon} \tag{37}$$

The share of public expenditure is

(38) $$s_g = \frac{1-\alpha}{\mu}\frac{\tau^Y + \tau^N}{1+\tau^N} + \frac{\tau^{\Pi}\left(1-\tau^Y\right) + \tau^Y\left[1+\left(\varepsilon-1\right)\alpha\right]}{\varepsilon}$$

By combining equations (31) and (33), we obtain the share of investment:

(39) $$s_i = \frac{\alpha\delta\left(1-\tau^Y\right)}{\left(\rho+\delta\right)}\frac{\varepsilon-1}{\varepsilon}$$

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

(40) $$s_c = 1 - s_g - \frac{\alpha\delta\left(1-\tau^Y\right)}{\mu\left(\rho+\delta\right)}$$

After some algebra, we obtain the steady state level of aggregate employment:[5]

(41) $$N = \frac{\left(1-\alpha\right)\left(\rho+\delta\right)\left(1-\tau^Y\right)}{\nu\left[\left(\rho+\delta\right)\left(1-s_g\right)\left(1+\tau^N\right)\mu - \alpha\delta\left(1-\tau^Y\right)\left(1+\tau^N\right)\right] + \left(1-\alpha\right)\left(\rho+\delta\right)\left(1-\tau^Y\right)}$$

After some tedious algebra, we can rewrite: $N = \left(1-\lambda\right)N^o + \lambda\left(1+\nu\right)^{-1}$, $C = \nu^{-1}W\left(1-N\right)\left(1-\tau^Y\right)$, $C^o = W\left(1+\nu\right)^{-1}\left(1-\tau^Y\right)$. By combining these aggregate equations, it is possible to obtain the consumption steady state ratios, by using $1 = \left(1-\lambda\right)\gamma_o + \lambda\gamma_r$, in fact, it follows that $\gamma_o = \frac{C^o}{C} = \frac{1-\lambda\gamma_r}{1-\lambda}$ and $\gamma_r = \frac{C^r}{C} = \frac{\nu}{1+\nu}\frac{1}{1-N}$.

In our framework, the steady state properties consist of zero-inflation and zero-debt. Disregarding on tax rate, the resulting linear equations of the firm's optimality conditions are:

(42) $$y_t = \alpha k_{t-1} + \left(1-\alpha\right)n_t$$

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

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

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

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. $\widehat{\left(MC\right)}_t = -\hat{\mu}_t$ in logs.

The log-linearization of the production function (17) and of the first order conditions ((22) and (23)) gives us the transition dynamic of the output (42) and the input demand schedules ((43) and (44)).

[5] See the appendix for details.

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 (24) in a standard manner.[6]

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

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

By rewriting the Ricardian leisure as a function of the aggregate employment (notice that $n_t = (1-\lambda)\gamma_o n_t^o$, 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 condition for Ricardian and Non Ricardian consumers can be rewritten as: $w_t - p_t = c_t^r$, $w_t - p_t = c_t^o - \frac{N}{(1-\gamma_o N)(1-\lambda)} n_t$ $c_t^o = E_t c_{t+1}^o - \frac{1}{\sigma}(r_t - E_t \pi_{t+1}) + \frac{(1-\sigma)\nu}{\sigma(1-\gamma_o N)(1-\lambda)} \Delta n_{t+1}$. Both the labor supply schedules depend positively on the income tax rate since the latter affects the budget constraint of both the consumers. Only Ricardian consumers, instead, take account of the employment since the level of the employment of the rule of thumb is constant. The Euler equation is standard except for the presence of the deviations in employment. The presence of the deviations in employment is justified 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:

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

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:

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

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

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

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

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

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:

(51) $$s_g g_t = \frac{\tau^Y \alpha}{\mu}\left(r_t^k - p_t + k_{t-1}\right) + \frac{\tau^Y\left(1-\tau^\Pi\right)+\tau^\Pi}{\varepsilon}\left(d_t - p_t\right) + \frac{\left(1-\alpha\right)\left(\tau^Y + \tau^N\right)\left(w_t - p_t + n_t\right)}{\mu\left(1-\tau^Y\right)}$$

where s_g is given by equation (38).

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

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

The central bank set the growth of interest rate in according to a standard Taylor rule:

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

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

4. Calibration and Analysis of Equilibrium Stability

We can now combine equilibrium conditions (42)-(54) to obtain a system of difference equations describing the log-linearized equilibrium dynamics of our model economy. The system is composed of 13 equations in 13 unknowns (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, $d_t - p_t$).

We use numerical methods for studying the uniqueness of the equilibrium and to provide a theoretical reason to the conditions that guarantee the uniqueness of equilibrium. More precisely, we will focus on the difference between our conditions and those stressed by Galì *et al.* (2004) for the case of lump-sum taxation in order to check if the latter can be generalized.

We calibrate our model following Galì *et al.* (2003), to compare the stabilization properties of a Taylor rule to their results. The labor disutility is set to obtain a steady state employment equal to $1/2$ without tax distortions as in Galì *et al*. (2003). Tax rates are set according to Busato *et al.* (2005) whereas monetary policy follows a standard Taylor rule. The table below summarizes the value assumed for the parameters.

Table 1 – Model calibration

Deep parameters	$\beta = 0.99$	$\varphi = 1$	$\sigma = 1$	$\eta = 1$
	$\alpha = 0.33$	$\varepsilon = 6$	$\delta = 0.025$	$\nu = 0.7$
Calvo's parameter	$\omega = 0.75$	$\lambda = 0.8$		
Monetary policy	$\theta_{\pi} = 1.5$	$\theta_{y} = 0.5$		
Tax rates	$\overline{\tau}^{\Pi} = 0.353$	$\overline{\tau}^{N} = 0.153$	$\overline{\tau}^{Y} = 0.12$	

Before stressing our results, it is useful to briefly discuss those of Galì *et al.* (2003, 2004) since our model generalizes their approach. In our framework, in fact, Galì *et al.* (2003) emerges as a particular case (i.e. assuming all the tax rates equal to zero).

Galì and coauthors show that the presence of rule-of-thumb consumers can dramatically change the properties of the interest rate set accordingly a Taylor rule. More precisely, 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. Both frictions are necessary for having indeterminacy. Once that the Blanchard and Kahn's (1980) conditions are not satisfied, the equilibrium may be indeterminate and thus displaying sunspot fluctuations even when the interest rate rule satisfies the Taylor principle.

The above results are driven by two imperfections: the presence of rule-of-thumb and counter-cyclical markups. A decline in markups, associated to an increase in the economic activity, allows real wages to increase (see equation (44) disregarding taxes). Then the increase in real wages generates inflation and a boom in consumption among non Ricardian consumers. If the weight of the rule-of-thumb is sufficiently large, the rise in their consumption will more than offset the effect of the rise in interest rate on Ricardian consumption. In other words, the high share of rule-of-thumb can invert the mechanism of the Taylor principle. A shock in economic activity and inflation can be self-fulfilled, and fluctuations are induced by indeterminacy in the equilibrium path. That possibility is facilitated by a high relative risk aversion, since it dampens the response of the consumption of Ricardian households (as we can see in equation (48)).

In our framework, this sunspot mechanism stressed by Galì *et al.* (2003) can be ruled out by introducing a positive corporate tax rate. Since the corporate tax rate burdens dividends, a decline in markups is now associated to a reduction in government expenditure. Because of the consequent reduction of aggregate demand the expansionary mechanism is hindered; therefore, the increase in non-Ricardian consumption can be more than offset by the decrease of public expenditure.

Corporate tax rate, by burdening markups, is able to stabilize the economy when the Taylor rule is unable to do it. Table 2 shows clearly that when the share of rule of thumb consumers is high enough, only a small threshold rate on profits could guarantee the uniqueness of the equilibrium, given that the Taylor rule needs a very high threshold inflation coefficient. By contrast, an increase in labor or income tax rate implies an increase in government expenditure, even if the markups decline, and so the regions of indeterminacy are not modified.

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

λ	θ_π	τ_π
0.1	0.94	0
0.2	0.94	0
0.3	0.94	0
0.4	0.94	0
0.5	0.94	0
0.6	0.94	0
0.7	3.7	0.07
0.8	12.2	0.26
0.9	24.4	0.44

In our calibration, taxation on profits affects conditions for indeterminacy: sunspots are less likely to be observed under fiscal distortions (see figure 1 below). As point out by Galì *et al.* (2003), results are strongly affected by the relative risk aversion and degree of stickiness. In our framework these effects are depicted in figure 1.

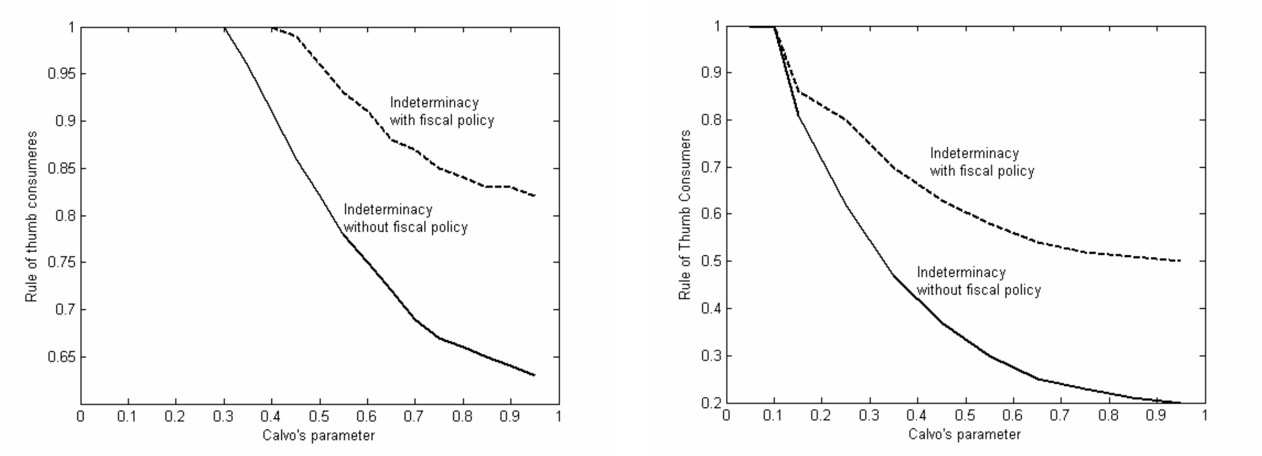
The relative risk aversions may have strong effects on determinacy properties of a Taylor rule. Figure 1 shows the change of the regions of indeterminacy for the case of $\sigma = 1$ (panel (a)) and $\sigma = 5$ (panel (b)). When $\sigma = 1$ the weight of the Ricardian-consumption reduction induced by monetary restriction is more important, indeterminacy requires a larger size of rule-of-thumb consumers relative to the case of $\sigma = 5$.[7]

Regarding the Calvo's parameter, in New Keynesian models, the impact of the current output (via markup) on current inflation by the Phillips curve is larger for low values of the Calvo's parameter. Then the Taylor principle does not hold and multiple solutions become possible.[8]

[7] Robustness of our results is also shortly discussed below and sensitivity analysis provided by appendix B.

[8] The indeterminacy caused by the excessive response of monetary policy has been emphasized by Bernanke and Woodford (1997). See also Clarida *et al*. (1998 and 1999) and Woodford (2004).

Figure 1 – Regions of indeterminacy



(a) (b)

By considering steady state value of employment smaller than 1/2, which is a smaller value than those commonly used in the literature, the share of rule of thumb consumers necessary to modify the regime of determinacy becomes higher than values presented in the case of Galì *et al* (2004). In fact, an equilibrium value of employment of 1/3 rises the share of rule-of-thumb consumers necessary for an indeterminacy regime to about 0.8, a value very similar to our result in presence of fiscal distortions, despite the *ceteris paribus* calibration used by Galì *et al* (2003, 2004), i.e. employment equal to 1/2. Therefore, the lack of robustness of their findings is emphasized by a lower employment steady state value since a very small corporate tax structure is more likely to remove regions of indeterminacy in presence of a monetary Taylor rule.

Summarizing, we show that Galì *et al.* (2004) is not indifferent to fiscal policy structure. Our general result is that fiscal policy distortion on profits facilitates the Taylor criterion since, in such a case, sunspot-driven fluctuations in the business cycle are less likely to be observed. This occurs because when a sunspot mechanism driven by a decline in markups could act the taxation on profits it dampens the aggregate demand, through the reduction of government expenditure. Hence it breaks the movement leaded by the animal spirit hypothesis at the heart of the sunspot mechanism, i.e., the self-fulfilling prophecy of a reduction in markups. In our model, corporate taxation implies a new conjoint fiscal and monetary stabilization. The Taylor rule is generally known as a compelling criterion of policy stabilization, but we have proved that it does not hold if general conditions are present, as e.g. fiscal distortions. We have in fact verified that when it fails fiscal policy could substitute the monetary policy in order to stabilize the economy.

6. Concluding Remarks

Following the recent developments of literature on rule-of-thumb consumers in New Keynesian monetary model, we have analyzed the support of monetary and fiscal policies to saddle-path solutions by studying the determinacy of the rational expectation equilibrium. By considering non-lump-sum taxes and balanced budget, we have shown that standard models augmented with rule-of-thumb consumers and fiscal policies are not indifferent to the taxation structure.

Our general result is that fiscal policy is non-neutral with respect to equilibrium determinacy since fiscal distortions under balanced budget policy facilitate the stabilizing properties of the Taylor rule by restricting the possibility of sunspot-driven fluctuations in the business cycle, stressed by recent literature. More in detail, an increase in profit tax rate makes sunspot equilibria less likely to emerge.

The rationale for our result is as follows. Sunspots or the animal spirit mechanism are the result of the self-fulfilling prophecy of a reduction in markups: since a decline in markups is associated to a reduction in government expenditure because of the corporate tax rate burdens dividends, fiscal distortions on profits dampen the aggregate demand, through the reduction of government expenditure, and make sunspot equilibria less likely to emerge. The size of effects on government expenditure depends on the profit tax rate. As result, the corporate tax rate, by burdening markups, stabilizes the economy when the Taylor rule is unable to do it. If the share of rule of thumb consumers is high enough, only a small rate on profits could guarantee the uniqueness of the equilibrium, given that the Taylor rule needs a very high coefficient to respond to the inflation and thus non-conventional results found in the case of a large number of rule-of-thumb consumers do not apply.

Acknowledgments

The authors would like to thank to G. Ciccarone, F. Giuli and E. Marchetti for useful discussions on preliminary drafts.

Appendix A – Labor disutility and steady state employment

The steady-state level of aggregate employment is obtained as follows.

(a.1) $$\frac{N}{1-N}=\frac{1}{\nu}\frac{(\varepsilon-1)(1-\alpha)}{s_c\varepsilon}\frac{1-\tau^Y}{1+\tau^N}=\frac{1}{\nu}\frac{(\varepsilon-1)(1-\alpha)(\rho+\delta)}{\varepsilon(1-s_g)(\rho+\delta)-\alpha\delta(1-\tau^Y)(\varepsilon-1)}\frac{1-\tau^Y}{1+\tau^N}$$

(a.2) $$N=\frac{N}{1-N}\left(\frac{N}{1-N}+1\right)^{-1}=\frac{(1-\alpha)(1-\tau^Y)}{(1-\alpha)(1-\tau^Y)+\mu\nu s_c(1+\tau^N)}$$

By using equation (40), after tedious algebra, the above expression can be also rewritten as:

(a.3) $$N=\frac{(1-\alpha)(\rho+\delta)(1-\tau^Y)}{\nu\left[(\rho+\delta)(1-s_g)(1+\tau^N)\mu-\alpha\delta(1-\tau^Y)(1+\tau^N)\right]+(1-\alpha)(\rho+\delta)(1-\tau^Y)}$$

Equation (a.3) with equation (38) determines the level of employment as a function of the deep parameters only. It can be rewritten as:

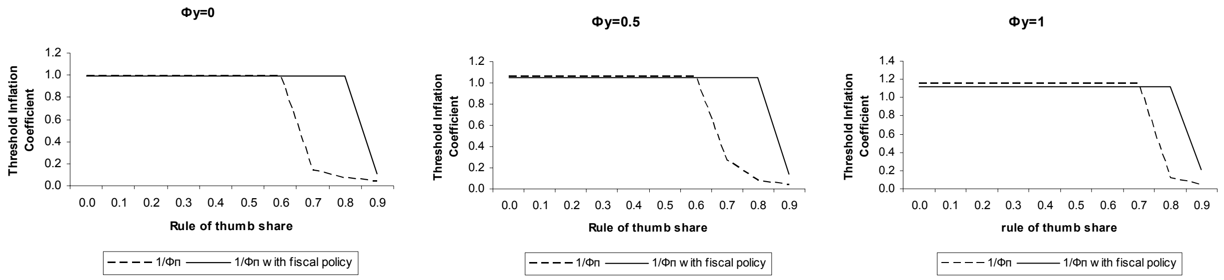
(a.4) $$\nu=\frac{(1-\alpha)(\rho+\delta)(1-\tau^Y)}{\varphi\left[(\rho+\delta)(1-s_g)(1+\tau^N)\mu-\alpha\delta(1-\tau^Y)(1+\tau^N)\right]},$$

which can be used to find the labor disutility consistent with a given level of employment.

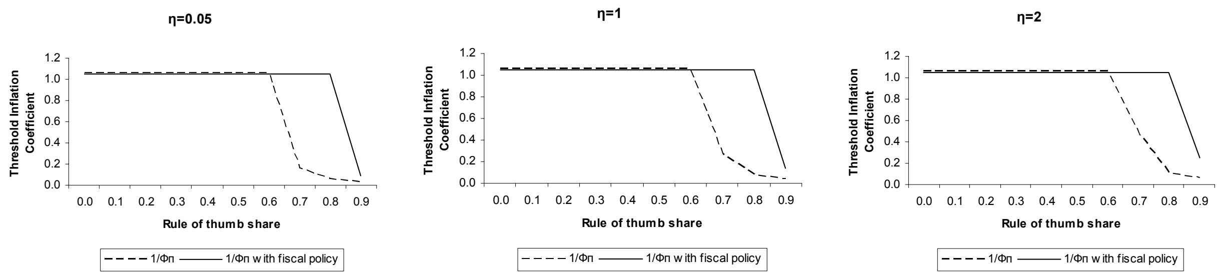
Appendix B – Sensitivity Analysis

Table 1B – Sensitivity analysis on output coefficient, capital adjustment cost, and labor elasticity

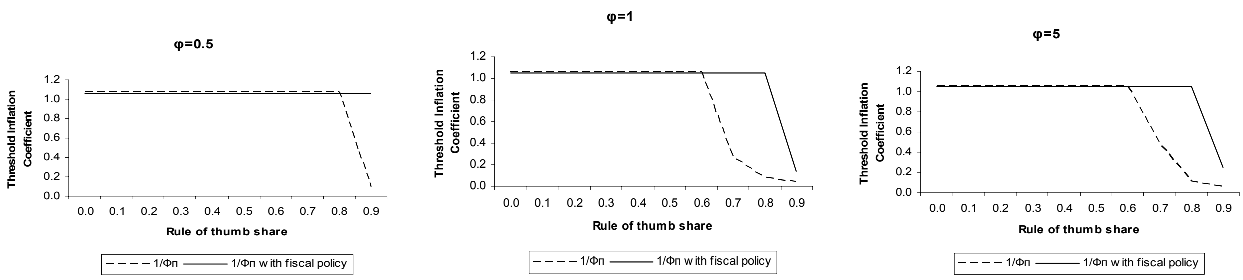
a) Output coefficient



b) Capital adjustment costs



c) Labor supply elasticity



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