

# Rule of Thumb Consumers Meet Sticky Wages

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## Abstract

It has been argued that rule of thumb consumers substantially alter the determinacy properties of interest rate rules and the dynamics of an otherwise standard new-keynesian model. In this paper we show that nominal wage stickiness helps restoring standard results. Key findings are that when wages are sticky i) the Taylor Principle returns the necessary condition for equilibrium determinacy; ii) consumption rises in response to an innovation in government spending if monetary policy is characterized by interest rate smoothing and by a moderately anti-inflationary stance. Our results help explaining the reduction in the expansionary effects of fiscal shocks observed in the U.S. after 1980.

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# 1 Introduction

The recent macroeconomic literature has seen the introduction of "rule of thumb consumers" into the representative agent framework. Such agents, who cannot use financial markets to smooth consumption over time, but consume their available labor income in each period, stand next to standard forward looking agents. This set-up was originally developed by Mankiw (2000) to account for the empirical relationship between consumption and disposable income, which seems stronger than suggested by the permanent income hypothesis.

More recently it has been shown that introducing rule of thumb, or non ricardian, consumers within the New Keynesian framework leads to substantially different predictions from those delivered by a canonical model.<sup>1</sup>

In this paper we generalize the New Keynesian framework with capital accumulation and rule of thumb consumers to allow for nominal wage stickiness *a la* Calvo. Our key findings are that wage stickiness: i) alters the determinacy conditions of simple interest rate rules; ii) modify the impulse response function of the model economy after a government spending shock.

Gali, Lopez-Salido and Valles (2004, GLV (2004) henceforth), study determinacy properties of interest rate rules in a sticky-prices economy with a fraction of rule of thumb consumers and capital accumulation. They show that when strong price stickiness coexists with a large share of rule of thumb agents determinacy of the rational expectations equilibrium (*REE*) requires the central bank to adopt a Reinforced Taylor Principle, whereby the inflation coefficient response is considerably above unity. The same issue is considered by Bilbiie (2008)

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<sup>1</sup>The simple heterogeneity between households we have described, breaks the Ricardian Equivalence. For this reason rule of thumb consumers are also defined as non ricardian consumers and it what follows we will use the two definitions interchangeably. Symmetrically standard forward looking households are defined as ricardian households.

and Di Bartolomeo and Rossi (2005) who provide an analytical treatment, but neglect capital accumulation. In particular, Bilbiie (2008) shows that a low elasticity of labor supply together with a sufficiently large share of non ricardian agents leads to an equilibrium where the increase in the real interest rate coexists with higher aggregate demand. In this case determinacy may require monetary policy to follow an Inverted Taylor Principle, whereby the central bank lowers the real interest rate in response to higher inflation.

We find that even a mild degree of wage stickiness restores the standard Taylor Principle as a necessary and sufficient condition for equilibrium determinacy under any empirically plausible parameterization. Nominal wage stickiness dampens variations in the real wage associated to shocks which affect economic activity. This helps preventing variations in aggregate demand driven by changes in consumption of non ricardian agents. As a result the Central Bank can manage aggregate demand and rule out the self realizations of non fundamental shocks resorting to standard policy prescriptions.

Turning to the effect of fiscal shocks, Galí, Lopez-Salido and Valles (2007, GLV (2007) henceforth) argue that rule of thumb consumers constitute a potential solution to the so called *Government Spending Puzzle*. Blanchard and Perotti (2002) consider U.S. time series data between 1960 and 1997. They provide VAR evidence suggesting that an innovation in government spending causes a persistent rise in private consumption. Similar findings are reported by Fatas and Mihov (2001). Nevertheless standard DSGE models predict that a positive shock to government purchases will have a contractionary effect on consumption.<sup>2</sup> The literature has identified this sharp contrast between the implications of the theory on one hand, and empirical results on the other, as a puzzle. GLV (2007) show that the interaction between rule of thumb consumers, sticky prices and deficit financing delivers a positive

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<sup>2</sup>The reason is that an increase in government spending generates a negative wealth effect which induces forward looking households to consume less and to work more.

response of aggregate consumption to an innovation in government spending. However, in their model the crowding in of aggregate consumption is obtained through a strong response of the real wage to the fiscal shock which boosts consumption of non ricardian agents. Such a sharp increase in the real wage is at odds with the evidence. Burnside *et al* (2004) estimate a negative response of the real wage to a spending innovation, while Blanchard and Perotti (2002) and Fatas and Mihov (2001) identify a positive but limited response.

Wage stickiness reduces the procyclicality of the real wage. As a result a large response of the real wage to a government spending shock is prevented. In this case the sign of the impact response of aggregate consumption to the spending shock depends on the parameterization of the model and on the design of monetary policy.

In particular, assuming a monetary policy rule which reacts solely to inflation and values of the elasticity of marginal disutility of labor consistent with the empirical evidence, consumption crowds-out. Restoring a positive impact response of aggregate consumption to government spending shocks requires an interest rate rule characterized by a relevant degree of interest rate smoothing. However, as the monetary policy stance becomes more anti-inflationary, the response of the main macroeconomic variables to fiscal shocks is attenuated.

Perotti (2005) provides VAR evidence for the U.S. suggesting a relevant reduction in the expansionary effects of public spending shocks on output and consumption after 1980. Our analysis supports the view, put forward by Perotti (2005) and Bilbiie *et al* (2008), that the more anti-inflationary policy pursued by the Fed after the early 1980s plays a major role at explaining the change in the transmission of fiscal shocks.<sup>3</sup>

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<sup>3</sup>Clarida *et al* (2002) and more recently Bilbiie *et al* (2008) estimates forward looking interest rate rules for the U.S. They find a much larger inflation coefficient response in a post-1979 sample period with respect to the pre-1979 sample. Clarida *et al* (2000) also verify that this result is robust to alternative specifications of the interest rate rule.

Results are robust to various specifications of the Taylor rule used in the literature, including one which reacts to wage inflation.

The remainder of the paper is laid as follows. Section 2 and 3 outline the model and its log-linearized version. Section 4 contains the main results. Section 5 discusses the policy implications of the analysis. Section 6 verifies the robustness of our results to alternative interest rate rules. Section 7 concludes.

## 2 The Model

### 2.1 Households

There is a continuum of households indexed by  $i \in [0, 1]$ . As in GLV (2004) and GLV (2007), households in the interval  $[0, \lambda]$  cannot access financial markets and do not have an initial capital endowment. These agents simply consume their available labor income in each period. The rest of the households on the interval  $(\lambda, 1]$  is composed by standard ricardian households who have access to the market for physical capital and to a full set of state contingent securities. Ricardian households hold a common initial capital endowment. The period utility function is common across households and it has the following separable form

$$U_t = u [C_t(i)] - v [L_t(i)] \tag{1}$$

where  $C_t(i)$  is agent  $i$ 's consumption and  $L_t(i)$  are labor hours.<sup>4</sup>

We assume a continuum of differentiated labor inputs indexed by  $j \in [0, 1]$ . As in Schmitt-Grohé and Uribe (2005), agent  $i$  supplies all labor inputs. Wage-setting decisions are taken by labor type-specific unions indexed by  $j \in [0, 1]$ . Given the wage  $W_t^j$  fixed by union  $j$ , agents stand ready to supply as many hours on labor market  $j$ ,  $L_t^j$ , as required by firms, that

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<sup>4</sup>The function  $u$  is increasing and concave while the function  $v$  is increasing and convex.

is

$$L_t^j = \left( \frac{W_t^j}{W_t} \right)^{-\theta_w} L_t^d \quad (2)$$

where  $\theta_w > 1$  is the elasticity of substitution between labor inputs. Here  $L_t^d$  is aggregate labor demand and  $W_t$  is an index of the wages prevailing in the economy at time  $t$ . Formal definitions of labor demand and of the wage index can be found in the section devoted to firms. Agents are distributed uniformly across unions, hence aggregate demand of labor type  $j$  is spread uniformly between all households.<sup>5</sup> It follows that the individual quantity of hours worked,  $L_t(i)$ , is common across households and we will denote it with  $L_t$ . This must satisfy the time resource constraint  $L_t = \int_0^1 L_t^j dj$ . Combining the latter with (2) we obtain

$$L_t = L_t^d \int_0^1 \left( \frac{W_t^j}{W_t} \right)^{-\theta_w} dj \quad (3)$$

The labor market structure rules out differences in labor income between households without the need to resort to contingent markets for hours. The common labor income is given by

$$L_t^d \int_0^1 W_t^j \left( \frac{W_t^j}{W_t} \right)^{-\theta_w} dj.$$

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<sup>5</sup>Thus a share  $\lambda$  of the associates of the unions are non ricardian consumers, while the remaining share is composed by non ricardian agents.

<sup>6</sup>Erceg *et al* (2000), assume, as in most of the literature on sticky wages, that each agent is the monopolistic supplier of a single labor input. In this case, assuming that agents are spreaded uniformly across unions allows to rule out differences in income between households providing the same labor input (no matter whether they are ricardian or not), but it does not allow to rule out difference in labor income between non ricardian agents that provide different labor inputs. This would amount to have an economy populated by an infinity of different individuals, since non ricardian agents cannot share the risk associated to labor income fluctuations. Although this framework would be of interest, it would imply a tractability problem.

### 2.1.1 Ricardian Households.

Ricardian Households' time  $t$  nominal flow budget reads as

$$\begin{aligned} & P_t (C_t^o + I_t^o) + (1 + R_t)^{-1} B_t^o + E_t \Lambda_{t,t+1} X_{t+1} \\ \leq & X_t + L_t^d \int_0^1 W_t^j \left( \frac{W_t^j}{W_t} \right)^{-\theta_w} dj + R_t^k K_{t-1}^o + B_{t-1}^o + P_t D_t^o - P_t T_t^o \end{aligned} \quad (4)$$

In each time period  $t$ , ricardian agents can purchase any desired state-contingent nominal payment  $X_{t+1}$  in period  $t+1$  at the dollar cost  $E_t \Lambda_{t,t+1} X_{t+1}$ . The variable  $\Lambda_{t,t+1}$  denotes the stochastic discount factor between period  $t+1$  and  $t$ . The expression  $L_t^d \int_0^1 W_t^j \left( \frac{W_t^j}{W_t} \right)^{-\theta_w} dj$  represents labor income and  $R_t^k K_{t-1}^o$  is capital income obtained from renting the capital stock to firms at the nominal rental rate  $R_t^k$ . Nominal dividends received from the ownership of firms are denoted by  $P_t D_t^o$ , while  $B_t^o$  is the quantity of nominally riskless bonds purchased in period  $t$  at the price  $(1 + R_t)^{-1}$  and paying one unit of the consumption numeraire in period  $t+1$ . Finally,  $P_t T_t^o$  represent nominal lump sum taxes. As in GLV (2007), the household's stock of physical capital evolves according to:

$$K_t^o = (1 - \delta) K_{t-1}^o + \sigma \left( \frac{I_t^o}{K_{t-1}^o} \right) K_{t-1}^o \quad (5)$$

where  $\delta$  denotes the physical rate of depreciation. Capital adjustment costs are introduced through the term  $\sigma \left( \frac{I_t^o}{K_{t-1}^o} \right) K_{t-1}^o$ , which determines the change in the capital stock induced by investment spending  $I_t^o$ . The function  $\sigma$  satisfies the following properties:  $\sigma'(\cdot) > 0$ ,  $\sigma''(\cdot) \geq 0$ ,  $\sigma'(\delta) = 1$ ,  $\sigma(\delta) = \delta$ . Thus, adjustment costs are proportional to the rate of investment per unit of installed capital. Ricardian households face the, usual, problem of maximizing the expected discounted sum of instantaneous utility subject to constraints (4) and (5). Let  $\nu_t$  and  $Q_t$  denote the Lagrange multipliers on the first and on the second constraint respectively. The first order conditions (FOCs) with respect to  $C_t^o$ ,  $I_t^o$ ,  $B_t^o$ ,  $K_t^o$ ,  $X_{t+1}$  are

$$u_c(C_t^o) = \nu_t P_t \quad (6)$$

$$\frac{1}{\phi' \left( \frac{I_t^o}{K_{t-1}^o} \right)} = q_t \quad (7)$$

$$\frac{1}{(1 + R_t)} = \beta E_t \frac{\nu_{t+1}}{\nu_t} \quad (8)$$

$$Q_t = E_t \left\{ \Lambda_{t,t+1} \left[ R_{t+1}^k + Q_{t+1} \left( (1 - \delta) - \phi' \left( \frac{I_{t+1}^o}{K_t^o} \right) \frac{I_{t+1}^o}{K_t^o} + \phi \left( \frac{I_{t+1}^o}{K_t^o} \right) \right) \right] \right\} \quad (9)$$

$$\Lambda_{t,t+1} = \beta \frac{\nu_{t+1}}{\nu_t} \quad (10)$$

where  $\beta = \frac{1}{1+\rho}$  represents the discount factor,  $\rho$  is the time preference rate and  $q_t = \frac{Q_t}{P_t}$  is the real shadow value of installed capital, i.e. Tobin's Q. Substituting (6) into (10) we obtain the definition of the stochastic discount factor  $\Lambda_{t,t+1} = \beta \frac{u_c(C_{t+1}^o)}{P_{t+1}} \frac{P_t}{u_c(C_t^o)}$  while combining (10) and (8) we recover the following arbitrage condition on the asset market

$$E_t \Lambda_{t,t+1} = (1 + R_t)^{-1}$$

### 2.1.2 Non Ricardian Households.

Non ricardian agents do not hold physical capital neither enjoy firms' profits in the form of dividend income. The nominal budget constraint of a typical non ricardian household is given by

$$P_t C_t^{rt} = L_t^d \int_0^1 W_t^j \left( \frac{W_t^j}{W_t} \right)^{-\theta_w} dj - P_t T_t^{rt} \quad (11)$$

Agents belonging to this class are forced to consume available income in each period and delegate wage decisions to unions. For these reasons there are no first order conditions with respect to consumption and labor supply. Similarly to GLV (2007) we let lump sum taxes (transfers) paid (received) by non ricardian households differ by those relative to ricardian.



## 2.2 Wage Setting

Nominal wage rigidities are modeled according to the Calvo (1983) mechanism. In each period a union faces a constant probability  $1 - \xi_w$  of being able to reoptimize the nominal wage. We extend the analysis in GVL (2007) and assume that the nominal wage newly reset at  $t$ ,  $\widetilde{W}_t$ , is chosen to maximize a weighted average of agents' lifetime utilities. The weights attached to the utilities of ricardian and non ricardian agents are  $(1 - \lambda)$  and  $\lambda$ , respectively. The union problem is

$$\max_{\widetilde{W}_t} E_t \sum_{s=0}^{\infty} (\xi_w \beta)^s \{ [(1 - \lambda) u(C_{t+s}^o) + \lambda u(C_{t+s}^{rt})] - v(L_{t+s}) \}$$

subject to (3), (4) and (11).<sup>7</sup> The FOC with respect to  $\widetilde{W}_t$  is

$$E_t \sum_{s=0}^{\infty} (\beta \lambda_w)^{t+s} \Phi_{t,t+s} \left\{ \left[ \lambda \frac{1}{MRS_{t+s}^{rt}} + (1 - \lambda) \frac{1}{MRS_{t+s}^o} \right] \frac{\widetilde{W}_t}{P_{t+s}} - \mu^w \right\} = 0 \quad (12)$$

where  $\Phi_{t,t+s} = v_L(L_{t+s}) L_{t+s}^d W_{t+s}^{\theta_w}$  and  $\mu^w = \frac{\theta_w}{(\theta_w - 1)}$  is the, constant, wage mark-up in the case of wage flexibility. The variables  $MRS_t^{rt}$  and  $MRS_t^o$  denote the marginal rates of substitution between labor and consumption of non ricardian and ricardian agents respectively.

## 2.3 Firms

In each period  $t$ , a final good  $Y_t$  is produced by a perfectly competitive firm combining a continuum of intermediate inputs  $Y_t(z)$  according to the following standard *CES* production function:

$$Y_t = \left( \int_0^1 Y_t(z)^{\frac{\theta_p - 1}{\theta_p}} dz \right)^{\frac{\theta_p}{\theta_p - 1}} \quad \text{with } \theta_p > 1 \quad (13)$$

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<sup>7</sup>Many reasons have been provided to justify the presence of non ricardian consumers. A few of them are miopia, fear of saving and transaction costs on financial markets. None of these is, however, in contrast with rule of thumb consumers delegating wage decision to a forward looking agency, in this case a trade union.

The producer of the final good takes prices as given and chooses the quantities of intermediate goods by maximizing its profits. This leads to the demand of intermediate good  $z$  and to the price of the final good which are respectively

$$Y_t(z) = \left( \frac{P_t(z)}{P_t} \right)^{-\theta_p} Y_t \quad ; \quad P_t = \left[ \int_0^1 P_t(z)^{1-\theta_p} dz \right]^{\frac{1}{1-\theta_p}}$$

Intermediate inputs are produced by a continuum of monopolistic firms indexed by  $z \in [0, 1]$  using as inputs capital services,  $K_{t-1}(z)$ , and labor services,  $L_t(z)$ . The production technology is given by:

$$Y_t(z) = [K_{t-1}(z)]^\alpha [L_t(z)]^{1-\alpha}$$

where  $0 < \alpha < 1$ . The labor input is defined as  $L_t(z) = \left( \int_0^1 \left( L_t^j(z) \right)^{\frac{\theta_w-1}{\theta_w}} dj \right)^{\frac{\theta_w}{\theta_w-1}}$ . Firm's  $z$  demand for labor type  $j$  and the aggregate wage index are respectively

$$L_t^j(z) = \left( \frac{W_t^j}{W_t} \right)^{-\theta_w} L_t(z) \quad ; \quad W_t = \left( \int_0^1 \left( W_t^j \right)^{1-\theta_w} dj \right)^{1/(1-\theta_w)}$$

The nominal marginal cost, common across producers, is given by

$$MC_t = \left( \frac{1}{\alpha} \right)^\alpha \left( \frac{1}{(1-\alpha)} \right)^{1-\alpha} W_t^{1-\alpha} (R_t^k)^\alpha,$$

while firm  $z$ 's real profits are given by  $D_t(z) = \left[ \frac{P_t(z)}{P_t} - \frac{MC_t}{P_t} \right] Y_t(z)$ .

**Price Setting** Intermediate producers set prices according to the same mechanism assumed for wage setting. Firms in each period have a fixed chance  $1 - \xi_p$  to reoptimize their price. A price setter takes into account that the choice of its time  $t$  nominal price,  $\tilde{P}_t$ , might affect not only current but also future profits. The FOC for price setting is:

$$E_t \sum_{s=0}^{\infty} (\beta \xi_p)^s \nu_{t+s} P_{t+s}^{\theta_p} Y_{t+s} \left[ \tilde{P}_t - \mu^p MC_{t+s} \right] = 0 \quad (14)$$

which can be given the usual interpretation.<sup>8</sup> Notice that  $\mu^p = \frac{\theta_p}{\theta_p-1}$  represents the markup over the price which would prevail in the absence of nominal rigidities.

<sup>8</sup>Recall that  $\nu_t$  is the value of an additional dollar for a ricardian household. It is the lagrange multiplier on ricardian households nominal flow budget constraint.

## 2.4 Government

The government nominal flow budget constraint is

$$P_t T_t + (1 + R_t)^{-1} B_t = B_{t-1} + P_t G_t \quad (15)$$

where  $P_t G_t$  is nominal government expenditure on the final good. We assume a fiscal rule of the form

$$t_t = \phi_b b_{t-1} + \phi_g g_t \quad (16)$$

where  $t_t = \frac{T_t - T}{Y}$ ,  $g_t = \frac{G_t - G}{Y}$  and  $b_t = \frac{B_t - B}{P}$ . We assume that  $g_t$  evolves according to the first order autoregressive process  $g_t = \rho_g g_{t-1} + \varepsilon_t^g$  where  $0 \leq \rho_g \leq 1$  and  $\varepsilon_t^g$  is a normally distributed zero-mean random shock to government spending.<sup>9</sup>

## 2.5 Monetary Policy

An interest rate-setting rule is required for the dynamic of the model to be fully specified. Our baseline specification features the central bank setting the nominal interest rate as a function of current inflation according to the following log-linear rule

$$r_t = \tau_\pi \pi_t \quad (17)$$

where  $r_t = \log \frac{(1+R_t)}{1+\rho}$  and  $\pi_t = \log \frac{P_t}{P_{t-1}}$ . In standard sticky prices models without capital accumulation, as in Woodford (2003) or Galí (2002), rule (17) ensures local uniqueness of the *REE* if it satisfies the *Taylor Principle*, i.e. if  $\tau_\pi > 1$ . In this case the rule is deemed

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<sup>9</sup>A sufficient condition for non explosive debt dynamics is

$$(1 + \rho)(1 - \phi_b) < 1$$

which is satisfied if

$$\phi_b > \frac{\rho}{1 + \rho}$$

We assume this condition is satisfied throughout.

to be “active” because it leads the nominal interest rate to rise more than proportionally in response to an increase in inflation. Carlstrom and Fuerst (2005) show that when the central bank follows a contemporaneous rule the determinacy conditions are, in general, not altered by capital accumulation.

## 2.6 Aggregation

We denote aggregate consumption, lump sum taxes, capital, investment, dividends and bonds with  $C_t$ ,  $T_t$ ,  $K_t$ ,  $I_t$ ,  $D_t$  and  $B_t$ , respectively. These are defined as

$$\begin{aligned} C_t &= \lambda C_t^{rt} + (1 - \lambda) C_t^o; & D_t &= (1 - \lambda) D_t^o & I_t &= (1 - \lambda) I_t^o; \\ T_t &= \lambda T_t^{rt} + (1 - \lambda) T_t^o; & K_t &= (1 - \lambda) K_t^o; & B_t &= (1 - \lambda) B_t^o. \end{aligned}$$

### 2.6.1 Market Clearing

The clearing of good and labor markets requires

$$\begin{aligned} Y_t(z) &= \left( \frac{P_t(z)}{P_t} \right)^{-\theta_p} Y_t^d \quad \forall z & Y_t^d &= Y_t; \\ L_t^j &= \left( \frac{W_t^j}{W_t} \right)^{-\theta_w} L_t^d \quad \forall j & L_t &= \int_0^1 L_t^j dz \end{aligned}$$

where  $Y_t^d = C_t + G_t + I_t$  represents aggregate demand,  $L_t^j = \int_0^1 L_t^j(z) dz$  is the demand of labor input  $j$  and  $L_t^d = \int_0^1 L_t^d(z) dz$  denotes firms’ aggregate demand of the composite labor input. The clearing condition of the market for physical capital is  $K_t = \int_0^1 K_t(z) dz$ .

## 2.7 Steady State

As in GLV (2007), steady state lump sum taxes are such that steady state consumption levels are equalized across agents. Variables without time subscript denote steady state values. Firm  $i$ ’s cost minimization implies

$$\frac{W}{P} = \frac{(1 - \alpha) Y}{\mu^p L}; \quad r^k = \frac{\alpha Y}{\mu^p K}$$

where  $\frac{K}{Y} = \frac{\alpha}{\mu^p(\rho+\delta)}$ . The ratio of government spending to output,  $\frac{G}{Y} = \gamma_g$ , is exogenously given. It follows that the steady state share of consumption on output,  $\gamma_c$ , equals

$$\gamma_c = 1 - \frac{\delta\alpha}{\mu^p(\rho+\delta)} - \gamma_g$$

which is independent of  $\lambda$ .

### 3 The Log-linearized Model

To make our results readily comparable to those in Bilbiie (2008) and GLV (2007) we adopt the same period utility function considered in their works:

$$u(C_t) = \log C_t \quad ; \quad v(L_t) = \frac{L_t^{1+\phi}}{1+\phi}$$

which features a unit intertemporal elasticity of substitution in consumption and a constant elasticity of the marginal disutility of labor  $v_{LL} = \phi$ .<sup>10</sup> In what follows lower case letters denote log-deviations from the steady state values. The log-deviation of the real wage, denoted by  $w_t$ , constitutes the only exception to this rule. The conditions which define the log-linear approximation to equations of the model are derived in GLV (2007) and we report them in the appendix. We provide, instead, a detailed derivation of the wage inflation curve and of the real wage schedule.

#### 3.1 Wage Inflation and the Real Wage Schedule

In the case of identical steady state consumption levels, agents have a common steady state marginal rate of substitution between labor and consumption. This implies that equation

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<sup>10</sup>The selected period utility belongs to the King-Plosser-Rebelo class and leads to constant steady state hours.

(12) can be given the following log-linear approximation

$$E_t \sum_{s=0}^{\infty} (\beta \xi_w)^{t+s} [w_{t+s} - mrs_{t+s}^A] = 0$$

where  $mrs_t^A = \lambda mrs_t^r + (1 - \lambda) mrs_t^o$  is a weighted average of the log-deviations between the marginal rates of substitution of the two agents. In what follows we will refer to  $mrs_t^A$  as to the average marginal rate of substitution. Given the selected functional forms, the (log)wage optimally chosen at time  $t$  is defined as

$$\log \widetilde{W}_t = \log \mu_w + (1 - \beta \xi_w) E_t \sum_{s=0}^{\infty} (\beta \xi_w)^{t+s} \{\log P_{t+s} + \log C_t + \phi \log L_t\}$$

Combining the latter with the following, standard, log-linear approximation of the wage index

$$\log W_t = (1 - \xi_w) \log \widetilde{W}_t + \xi_w \log W_{t-1}$$

we obtain the desired wage inflation curve

$$\pi_t^w = \beta E_t \pi_{t+1}^w - \kappa_w \mu_t^w \tag{18}$$

where  $\kappa_w = \frac{(1 - \beta \xi_w)(1 - \xi_w)}{\xi_w}$  and  $\mu_t^w = (\log W_t - \log P_t) - (\log \mu_w + \log C_t + \phi \log L_t)$  is the wage mark-up that unions impose over the average marginal rate of substitution.<sup>11</sup> Notice that since unions maximize a weighted average of agents' utilities, the wage inflation curve takes a standard form. Wage inflation, together with the log-linear version of the production function in the Appendix, lead to the following equation for the log-deviation of the time  $t$  real wage:

$$w_t = \Gamma w_{t-1} + \Gamma \beta (E_t w_{t+1} + E_t \pi_{t+1}) + \Psi y_t - \Psi \alpha k_{t-1} + \Gamma \kappa_w c_t - \Gamma \pi_t \tag{19}$$

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<sup>11</sup>As pointed out by Schmitt-Grohe and Uribe (2005), the coefficient  $\kappa_w$  is different from that in Erceg et al (2000), which is the standard reference for the analysis of nominal wage stickiness. The reason is that we have assumed that agents provide all labor inputs. In the more standard case in which each individual is the monopolistic supplier of a given labor input,  $\kappa_w$  would be equal to  $\frac{(1 - \beta \xi_w)(1 - \xi_w)}{\xi_w (1 + \phi \theta_w)}$  hence lower than in the case we consider.

where  $\Gamma = \frac{\xi_w}{(1+\beta\xi_w^2)}$  and  $\Psi = \frac{\phi}{1-\alpha}\Gamma\kappa_w$ . Under wage flexibility ( $\xi_w = 0$ ) equation (19) reduces to

$$w_t = \frac{\phi}{(1-\alpha)}y_t - \frac{\alpha}{(1-\alpha)}\phi k_{t-1} + c_t$$

which is the wage setting equation in GLV (2007). Two points are worth stressing. Firstly, wage stickiness reduces the coefficient on current output deviations, making the real wage less procyclical. Secondly, the coefficient on current output deviations increases linearly with the elasticity of marginal disutility of labor. Thus, for given wage stickiness, a higher value of  $\phi$  makes the real wage more procyclical. As we will see below these are the main driving forces behind our results.

## 4 Results

### 4.1 Calibration

The period length is one quarter. In the baseline parameterization we set  $\xi_w = 0.75$ , which implies an average duration of wage contracts of one year as suggested by the estimates in Smets and Wouters (2003) and Levine *et al* (2005). The parameters  $\alpha$  and  $\beta$  assume the standard values of  $\frac{1}{3}$  and 0.99 respectively. We take  $\phi = 5$  as our baseline value since in a model with a frictionless labor market it would lead to an intertemporal elasticity of substitution in labor supply  $\frac{1}{\phi} = 0.2$ , which is in line with the existing micro-evidence in Card (1991) and Pencavel (1986). However, we will evaluate the dependence of our results on the value of the elasticity of the marginal disutility of labor. The baseline value for the share of non ricardian consumers,  $\lambda$ , is 0.5. This is consistent with the estimates in Campbell and Mankiw (1989) and Muscatelli *et al* (2004). Remaining parameters are displayed in Table 1, and the reader can refer to the references reported in GLV (2007) for empirical evidence

supporting them.

## 4.2 Determinacy and the Taylor Principle

Figure 1 shows the region of the parameter space  $(\tau_\pi, \lambda)$  where the *REE* is unique. Other parameters are set at their baseline values. A first result is visually evident:

**Result 1. Determinacy and the Taylor Principle.** The Taylor Principle is a necessary and sufficient condition for equilibrium determinacy.

To build intuition we initially consider the case of flexible wages. Suppose that the level of economic activity starts increasing with no fundamental reason as hypothesized by GVL (2004). Inflation increases through the NKPC, triggering a response of the monetary authority. Under the Taylor Principle the real interest rate rises and ricardian agents reduce their consumption. However, in the presence of non ricardian agents, these are just partial effects. The increase in labor demand brought about by the sunspot in output together with price stickiness lead to a higher real wage. This generates a boom in non ricardian agents' consumption which, if  $\lambda$  is large enough, drives up aggregate demand. The implied variation in aggregate demand would make it possible to sustain the initial sunspot in output.

How does wage stickiness alter this mechanism? The key point is that wage stickiness dampens the response of the real wage to a rise in output of any given size. This prevents the large increase in labor income and helps precluding the large movement in non ricardian agents' consumption which sustained the sunspot under flexible wages. In this case the Taylor Principle, through its effect on the real interest rate and on ricardian agents' demand, suffices to ensure equilibrium uniqueness.

Notice that both a higher value of the elasticity of marginal disutility of labor,  $\phi$ , and a lower degree of wage stickiness (lower  $\xi_w$ ), with respect to the baseline, increase the output-



sensitivity of the real wage. Also a larger share of non ricardian agents,  $\lambda$ , would amplify the impact of variations in labor income on aggregate demand. Both these effects could help restoring the tendency to equilibrium indeterminacy notwithstanding the Taylor Principle.

For this reason we evaluate, with the aid of Figure 2, whether Result 1 is affected by alternative combinations of the afore mentioned parameters. Assuming that monetary policy obeys to the Taylor Principle ( $\tau_\pi = 1.5$ ), we depict the threshold value of the share of non ricardian agents as a function of the elasticity of marginal disutility of labor consistent with determinacy. The dashed line refers to the case of flexible wages ( $\xi_w = 0$ ), the dotted line to that of sticky wages with an average duration of wage contracts equal to two quarters ( $\xi_w = 0.5$ ), while the solid line refers to the baseline case ( $\xi_w = 0.75$ ). In the case of flexible wages, and under the baseline parametrization of the share of non ricardian agents, equilibrium is indeterminate for values of  $\phi$  larger than 0.46.<sup>12</sup> However the parameter space which leads to an indeterminate equilibrium in the case of wage stickiness (region B+C when wages have an average duration of two quarters, region C under the baseline parameterization) is a subset of that identified under wage flexibility (region A+B+C). Consider the case where wages last on average for two quarters. For values of  $\phi$  between 1 and 10 the value of  $\lambda$  should be as high as 0.6 for the equilibrium to be indeterminate. Under the baseline duration of wage contracts there is no value of  $\lambda$  consistent with indeterminacy when  $\phi$  varies in the specified range. Comparing these figures with the estimates of the importance of non ricardian agents provided by Campbell and Mankiw (1989) and Muscatelli *et al* (2004) for the U.S., that place this around 0.4–0.5, the share of non ricardian agents required to end up in the indeterminate region seems empirically implausible.

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<sup>12</sup>In a model with a competitive labor market this value would imply an elasticity of labor supply nearly equal to 2, much higher than that suggested by empirical evidence. Recall that GVL (2007) set  $\lambda = 0.5$  and  $\phi = 0.2$ , thus their parametrization is consistent with a unique equilibrium.

To make this finding fully transparent, Figure 3 depicts indeterminacy regions in the parameter space  $(\tau_\pi, \lambda)$  considering the baseline value of the elasticity of marginal disutility of labor. We consider alternative degrees of wage stickiness with respect to the baseline. In Panel *a* wages are flexible. When the share of non ricardian agents assume values larger than a certain threshold, 22 percent here, determinacy requires either a Reinforced Taylor Principle, as in GVL (2004), or an Inverted Taylor Principle, as in Bilbiie (2008).<sup>13</sup> However, when the average duration of wage contracts reaches two quarters (panel b), the standard Taylor Principle leads to equilibrium uniqueness for values of the share of non ricardian consumers up to 70 percent. Panel c shows that our results are not altered when the average duration of wage contracts is increased to ten quarters ( $\xi_w = 0.9$ ).

Similarly to GLV (2004) we find that strong price stickiness reduces the threshold value of the share of non ricardian consumers above which the Taylor Principle needs to be strengthened to enforce a unique *REE*.<sup>14</sup> A degree of price stickiness stronger than the baseline implies that a larger share of firms changes labor demand rather than prices in the face of a change in the demand for the final good. In this case a sunspot in output would lead to a relevant rise in the real wage, rendering the self-realization of the shock consistent with a low share of non ricardian agents.

However, nominal wage rigidity dampens the variations of the real wage associated to changes in labor demand and confines the need of a reinforced Taylor Principle to extreme parameterizations. In particular, under the baseline calibration, the standard Taylor Prin-

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<sup>13</sup>As mentioned in the Introduction, Bilbiie (2008) shows that in the presence of non ricardian agents the interest rate sensitivity of output may turn positive. In this case lowering the interest rate in response to inflationary pressure helps controlling aggregate demand.

<sup>14</sup>Notice that interaction between strong price stickiness and the presence of capital accumulation may require itself a strenghtening of the Taylor Principle. However, GVL (2004) show that determinacy holds under the standard Taylor Principle when the model is fully ricardian.

principle is a necessary and sufficient determinacy condition for values of the price stickiness parameter  $\xi_p \leq 0.79$ . This threshold value corresponds to an average lifetime of price contracts of 4.8 quarters, which is sensibly larger than that estimated in empirical analysis.<sup>15</sup>

#### 4.2.1 Interest Rate Smoothing

Empirical works on Taylor rules show that central banks tend to adjust the nominal interest rate in response to changes in economic conditions only gradually (e.g., Clarida *et al* 2000). Thus, in this section we explore the effects of rule of thumb consumers and wage stickiness on the determinacy properties when our interest rate rule is modified to be

$$r_t = \rho_r r_{t-1} + (1 - \rho_r) \tau_\pi \pi_t \tag{20}$$

With interest rate smoothing the definition of the Taylor principle becomes that monetary policy should be active in the long run. This means that the particular value of the interest rate smoothing coefficient,  $\rho_r \in (0, 1)$ , is irrelevant for determinacy, as long as the inflation response coefficient is strictly larger than one.<sup>16</sup> Figure 4 reports our numerical results concerning two scenarios. Panels *a* and *b* refer to the flexible wages case, while panels *c* and *d* depict determinacy regions under our baseline parameterization for wage stickiness. For each scenario we consider two alternative values for the smoothness parameter, namely  $\rho_r=0.5$  and  $\rho_r=0.8$ . Each panel represents determinacy regions in the parameter space  $(\tau_\pi, \lambda)$  holding the remaining parameters at their baseline values. Under price and wage stickiness

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<sup>15</sup>Nakamura and Steinsson (2008) find an average price duration of three quarters in the U.S. retail sector. Similar estimates are provided by Christiano *et al* (2005). In our baseline parameterization we follow most of the literature and set average price duration to four quarters. Reducing the degree of price stickiness would reinforce all the results presented in this paper. An analysis of the sensitivity of determinacy regions to the degree of price stickiness is reported in a companion appendix.

<sup>16</sup>Schmitt-Grohé and Uribe (2007) argue that this result is robust to the introduction of capital accumulation.

the (long-run) Taylor Principle ensures uniqueness for most values of  $\lambda$ , except for implausible large ones. Notice that this is not so when wages are flexible. In that case non-standard determinacy regions exist.

In sum, our analysis shows that rule of thumb consumers do not invalidate the relevance of the Taylor Principle when nominal wage stickiness, a well documented empirical fact, is considered.

### 4.3 Consumption and Government Spending Shocks

Figure 5 depicts the response of key variables to a one percent government spending shock under three polar parameterizations of the model we have outlined. Solid lines refer to the case where prices and wages are flexible, dotted lines correspond to the flexible wages-sticky prices scenario i.e. the GVL (2007) model, while dashed lines refer to the model with sticky wages and sticky prices. We consider the baseline parameterization for the share of non ricardian agents and the monetary policy rule. Importantly, the value of the elasticity of the marginal disutility of labor is that adopted by GVL (2007),  $\phi = 0.2$ , in all scenarios.

Consider the case of sticky wages. Nominal wage rigidity reduces the procyclicality of the real wage. This implies that a large response of the latter to a government spending shock is prevented. Output and hours, instead, rise strongly compared to what happens under the flexible prices-wages case. As a result consumption of non ricardian agents increases, but not as much as in the GVL model. However, aggregate consumption rises persistently. The reason is that under sticky wages consumption of ricardian agents does not diminish as much as in the two other cases considered.

Both the interest rate rule and the value of  $\phi$  play key roles for this result. Under the chosen parameterization of  $\phi$  wage stickiness implies an extremely low sensitivity of the real wage to changes in output and hours. In fact, although the rise in hours is basically

identical to that observed in the GVL model, the real wage barely changes on impact. The negligible increase in the real wage results into a mild change in real marginal costs and thus in inflation. Since the monetary policy rule reacts just to the latter the real interest rate shows a lower increase with respect to that observed both in the GVL setting and in the flexible prices-wages scenario. This translates into a moderate reduction in ricardian agents' consumption.

In figure 6 we report the response of some selected variables to a government spending shock in the sticky wages model under alternative values of the elasticity of marginal disutility of labor. In panel *a* we consider the baseline parametrization,  $\phi = 5$ . In panel *b* we consider the case of a unit elasticity,  $\phi = 1$ . We do not report the IRFs of the GVL (2007) model since as the elasticity of marginal disutility of labor increases the equilibrium of the flexible wages model quickly runs into indeterminacy under the standard Taylor Principle.<sup>17</sup> However, for comparison, we report the IRFs of the flexible prices-wages model.

As the elasticity of marginal disutility of labor approaches the values supported by the empirical evidence the response of the real wage to the innovation in government spending gets stronger, resulting in a lower rise in hours. The response of the real wage translates into a considerable variation in inflation which leads to a more relevant, with respect to the case analyzed earlier, reaction in the nominal and the real interest rate. This depresses consumption of ricardian consumers. The joint movement of real wage and hours dampens the change in consumption of non ricardian agents and, in the case of the baseline calibration,

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<sup>17</sup>As shown in the section on determinacy, given the baseline value of the share of non ricardian agents the GVL model results in an indeterminate equilibrium under the Taylor Principle for values of  $\phi$  larger than 0.46. In this case Figure 3 shows that determinacy would require either a Reinforced Taylor Principle or an Inverted Taylor Principle. In the first case aggregate consumption crowds-out given the strong response of the interest rate to inflation. In the second case fiscal shocks have non keynesian effects and lead to a reduction non just in aggregate consumption but also in output (see e.g. Bilbiie and Straub (2004)).

prevents an increase in aggregate consumption.<sup>18</sup> We are now ready to state the first result of this section

**Result 2. Impact response of aggregate consumption and  $\phi$ .** Under the baseline monetary policy rule the effect of a government spending shock on private consumption becomes quantitatively smaller as the elasticity of marginal disutility of labor,  $\phi$ , increases. When the latter assumes values consistent with the empirical evidence consumption crowds-out.

In the remainder of the section we will focus on the sticky wage model under the baseline, empirically plausible, parameterization of the elasticity of marginal disutility of labor and we will try to understand the relevance of the monetary policy stance for the transmission of fiscal shocks. In particular we aim at verifying whether government spending shocks induce a persistent rise in private consumption under a reasonable characterization of U.S. monetary policy.

Various papers estimate DSGE models with sticky prices using quarterly U.S. data. Canova (2009) uses Bayesian methods to estimate a basic New Keynesian model over the period 1955-2002. He assumes an interest rate rule of the form

$$r_t = \rho_r r_{t-1} + (1 - \rho_r) (\tau_\pi \pi_t + \tau_y y_t) \tag{21}$$

and obtains estimate of the inflation response coefficient and the output response coefficient equal to 1.71 and 0.02 respectively, with an interest rate smoothing parameter equal to 0.98. Di Bartolomeo *et al* (2009) adopt Bayesian techniques to estimate a New Keynesian model with rule of thumb agents over the period 1963:1-2003:2. Assuming the same rule as

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<sup>18</sup>The impact response of consumption becomes negative for value of  $\phi$  larger than 2.32. This implies that assuming  $\phi = 3$ , a value widely used in the literature, results in crowding out of aggregate consumption. Please see the working paper version for details.

in Canova (2009), they find a lower inflation response coefficient, equal to 1.49, an output response coefficient equal to 0.2 and a smoothing parameter equal to 0.8.

It has to be considered that consensus places a change in the monetary policy regime around 1980, when Paul Volcker came to office as chairman of the Fed. Clarida *et al* (2000) estimate Taylor rules using single equation techniques. They report an estimate of the long run inflation coefficient response equal to 2.15 for a post-1979 sample period while their corresponding estimate for the period up to 1979 is 0.83.<sup>19</sup> According to these estimates, monetary policy started fighting inflation more fiercely at the beginning of the Volcker-Greenspan era. Lubik and Schorfheide (2004) obtain similar results resorting to multivariate estimation of a canonical New Keynesian model. In their post 1982 sample, that excludes the Volcker-disinflation period, they estimate an inflation coefficient response equal to 2.2 together with an output coefficient equal to 0.3 and interest rate smoothing equal to 0.84. Figure 7 displays the response to a government spending shock under the baseline parametrization, but under alternative specifications of the interest rate rule (21). Each of them mirrors the empirical evidence just discussed.

Continuous line refer to the Di Bartolomeo et al (2009) estimation, dotted lines refers to estimation by Canova (2009), while dashed lines refer to the Lubik and Schorfheide (2004) estimates. Remarkably, aggregate consumption rises in the aftermath of the shock in all cases.

Notice that the monetary policy rules under analysis are characterized by a relevant degree

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<sup>19</sup>Clarida *et al* (2000) estimate a forward looking interest rate rule, however their results extend to alternative specifications of their baseline monetary policy rule such as that specified in (21). Bilbiee, Meier and Muller (2008) estimate a DSGE model with rule of thumb consumers and a forward looking interest rate rule using U.S. data. They find a considerable change in the way the nominal interest rate is adjusted in response to expected inflation over time. More precisely, they report an inflation coefficient response equal to 1.01 in the period 1957:1-1979:2 together with a coefficient value equal to 1.77 for the period 1983:1-2004:4.

of interest rate smoothing, which implies a radically different dynamic of the real interest rate with respect to that generated by the baseline policy rule. In particular, no matter the inflation response coefficient, the real interest rate decreases on impact. This limits the negative response of ricardian agents consumption and leads to a sizeable impact response of output, hours and thus of consumption of non ricardian agents.<sup>20</sup> The joint behavior of these variables eventually leads to an increase in aggregate consumption.

The effect of the fiscal shock on the main macroeconomic variables is more muted under the Lubik and Schorfheide specification of the policy rule, which is characterized by high inflation and output response coefficients. In this case the real interest rate does not get as negative as in the other cases, and does not boost the effects of the shock to the same extent.

Figure 8 helps understanding the role played by the monetary policy stance for the transmission of fiscal shocks on consumption. Considering alternative values of the output response coefficient, we identify combinations of the interest rate smoothing coefficient and the inflation response coefficient which lead to an increase in consumption in response to the spending shock. We emphasize three aspects. Firstly, in the absence of smoothing and output response, consumption displays a positive response to the shock just values of  $1 < \tau_\pi \leq 1.06$ , which are close to deliver equilibrium indeterminacy. Secondly, given the degree of smoothing, the likelihood of a positive impact response of consumption decreases as  $\tau_\pi$  gets larger, i.e. as monetary policy becomes more anti-inflationary. Thirdly, as the output response coefficient increases a higher degree of smoothing or a lower inflation response are required to observe a positive impact response of consumption. The main result of this section is the following:

**Result 3. Impact response of aggregate consumption and monetary policy.** Consumption

increases in response to a government spending shock when the interest rate rule is char-

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<sup>20</sup>Consumption of non ricardian agents decreases in response to the shock due to the negative wealth effect induced by an increase in government spending.



acterized by interest rate smoothing. As monetary policy responds to changes in output and adopts a more anti-inflationary policy stance the response of consumption becomes quantitatively smaller and less persistent.

To conclude we discuss the effect of alternative parameterizations of the share of non ricardian agents.<sup>21</sup> As in GVL (2007) the effect of spending shocks on aggregate consumption and output is stronger the larger the value of  $\lambda$ . Similarly the effects on labor demand and on the real wage increase as the share of rule of thumb agents gets larger. The pattern of the real wage is transmitted to price inflation and to the real interest rate since monetary policy obeys to the Taylor Principle. For this reason the response of ricardian consumers' consumption is lower the higher  $\lambda$ . This partly counterbalances the effect of the increase in non ricardian agents' demand on aggregate consumption.

## 5 Discussion

In this section we draw some implications of our results for the conduct of monetary and fiscal policy and their interaction. Throughout the paper we have assumed that fiscal policy is "Ricardian", i.e. that taxes respond sufficiently strongly to deviations of the stock of outstanding debt from its steady state level as to insure a stable debt dynamic.<sup>22</sup> Under this condition we have shown that, for any plausible share of non ricardian agents, the *REE* is unique when monetary policy satisfies the Taylor Principle. As a result the joint

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<sup>21</sup>We do not report IRFs to a government spending shock under alternative parametrizations of the share of non ricardian agents. The interested reader can find this analysis in the working paper version of this article.

<sup>22</sup>Notice that as in GVL (2007) we have assumed that the steady stock of debt is zero. Leith and Von Thadden (2008) point out that the level of steady state debt could affect determinacy conditions in a non ricardian framework.

design of monetary and fiscal policy needed for macroeconomic policies not to be a source of non-fundamental fluctuations is isomorphic to that which Leeper (1991) and Woodford (1996) have identified in a fully ricardian model. Namely, a unique *REE* is insured by the combination of an active interest-rate rule and a ricardian fiscal policy.<sup>23</sup>

Related to this issue we now assess two empirical findings which have recently received considerable attention. The first one concerns the historical conduct of monetary policy in the U.S. and its implications for macroeconomic volatility. As mentioned above, consensus places a change in the monetary policy regime around 1980. According to the estimates by Clarida *et al* (2000) and Lubik and Schorfhinde (2004) monetary policy in the U.S. switched from passive to active after Paul Volcker came to office as chairman of the Fed. Values of long run inflation response coefficient below one allow sunspot shocks to have real effects in standard new Keynesian models. This led Clarida *et al* (2000) to identify the conduct of monetary policy as a potential source of the large macroeconomic volatility registered in the U.S. during the 1970s. Bilbiie (2008), on the basis of the Inverted Taylor Principle argument, challenges this view. If the share of non ricardian agents was sufficiently large at that time, he argues, then the FED policy, by using a passive rule, was actually acting as to implement a unique *REE*. Our analysis shows that as long as nominal wages were sticky during the 1970s a passive policy would have itself been a source of instability for any reasonable value of the share of non ricardian agents. For this reason we view our determinacy result as supportive of the thesis proposed by Clarida *et al* (2000).

The second empirical finding we wish to address concerns, instead, the change in the transmission of fiscal shocks to the economy after 1980. Perotti (2005) and Bilbiie *et al* (2008) provide VAR evidence for the U.S. suggesting a relevant reduction in the expansionary

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<sup>23</sup>In a fully ricardian model if fiscal policy is “Non Ricardian”, equilibrium uniqueness requires a passive monetary policy. Notice that we do not consider Non Ricardian fiscal policies here.

effects of public spending shocks after the early 1980s. The afore mentioned authors argue that the more anti-inflationary policy stance pursued by Volcker and Greenspan with respect to their predecessors, together with a higher participation to the asset market (i.e. lower  $\lambda$ ) may account for the change in the transmission of fiscal shocks.

Our analysis supports the view that monetary policy alone plays a fundamental role for the transmission of fiscal shocks. A model with rule of thumb agents and nominal wage stickiness helps addressing the empirical evidence in Perotti (2005) and Bilbiie (2008) on the basis of the tightening of monetary policy observed after 1980. This is not the case when wages are flexible since the responses of variables such as the real wage, output and consumption remain stronger and more persistent than suggested by the empirical evidence no matter the tightening of the policy stance.

## 6 Robustness to Alternative Interest Rate Rules

In what follows we argue that our findings are robust to simple variant of the Taylor rules proposed in the literature. We consider rules which are specialization of the, general, instrumental rule

$$r_t = \rho_r r_{t-1} + (1 - \rho_r) (\tau_\pi E_t \pi_{t+i} + \tau_y E_t y_{t+i}) \quad (22)$$

When  $i = -1$ , (22) reduces to a backward looking rule, when  $i = 0$  it corresponds to a contemporaneous rule and when  $i = 1$  it becomes a forward looking rule. For each of the specifications mentioned we consider the case of inertia, with  $\rho_r = 0.8$ . The share of non ricardian agents is held at the baseline value.<sup>24</sup> Visual inspection of Figure 9 leads to the next result.

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<sup>24</sup>In the companion appendix we show that increasing the size of rule of thumb consumers does not determine relevant variations in determinacy regions.

**Result 4. Determinacy and non ricardian consumers.** Under most of the Taylor-type interest rate setting rules, the determinacy and indeterminacy regions for the model with non ricardian consumers featuring price-wage stickiness are similar to those identified in a fully ricardian economy.

The forward looking rule, depicted in panel *f*, shows a determinacy region which is severely restricted with respect to the case of a contemporaneous rule. As pointed out by Carlstrom and Fuerst (2005), forward looking rules increase the likelihood of sunspot fluctuations in the case of endogenous capital accumulation and should be implemented with care. Panels *a, c* and *e* suggest that nominal interest rate inertia makes indeterminacy less likely, no matter the rule followed by the central bank.<sup>25</sup>

Next we turn to the effect of government spending shocks. Figure 10 reports the response of aggregate consumption to a government spending shock under different specifications of the general rule (22). The left-column features policy rule which react just to inflation, as in our baseline case. When the interest rate rule is characterized by smoothing, with  $\rho_r = 0.8$ , we consider two alternative parameterizations of the inflation coefficient response:  $\tau_\pi = 1.5$  (middle-column) and  $\tau_\pi = 2.2$  (right-column). The first one is representative of the monetary policy attitude against inflation in the period going from 1960 to the beginning of this century, while the second is based on a post 1980 sample. Also, we report impulse response functions for three different parameterizations of  $\tau_y$ . We emphasize the following.

**Result 5. Aggregate consumption and interest rate rules.** No matter the interest rate rule adopted by the central bank, interest rate smoothing together with a moder-

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<sup>25</sup>In the companion appendix we consider a contemporaneous rule which reacts to wage inflation. In this case a necessary condition for determinacy is  $\tau_p + \tau_w > 1$ , where  $\tau_w$  is the wage inflation coefficient response. It should not be, by now, surprising that this is equivalent to the determinacy condition which holds in a fully ricardian model as shown by Schmitt-Grohe and Uribe (2007).

ately anti-inflationary policy stance enhances the possibility of a positive response of consumption to a government spending shock. Reacting to deviations of output from its steady state level reduces, instead, the likelihood of a positive impact response of consumption.

The earlier findings concerning the relationship between monetary policy and the transmission of fiscal shocks extend to most of the Taylor rules considered in the literature.<sup>26</sup>

## 7 Conclusions

We regard a framework where current income affects consumption possibilities as a promising step towards realism in economic modeling. In this case, however, it should not be ignored that the labor markets and the wage setting process are characterized by imperfections. In an economy populated by an exogenous share of non ricardian consumers, nominal wage stickiness affects both the response of aggregate variables to a government spending shock and the conditions for equilibrium determinacy. Specifically, consumption crowds-in after a government spending shock solely when the monetary policy rule is characterized by interest rate smoothing and by a moderately anti-inflationary stance. Our results help understanding the reduction in the expansionary effects of public spending shocks after the eighties given that, according to the evidence, the Fed's policy became more inflation averse in the same period.

Contrary to Bilbiie (2008) and GLV (2004) we have shown that the Taylor Principle implies equilibrium determinacy for any plausible parameterization of the share of non ricardian agents. This finding suggests that the determinacy properties of the model with non ricardian consumers strongly depend on the form of nominal rigidities considered. For this reason, we

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<sup>26</sup>The case of a central bank reacting to wage inflation is detailed in the companion appendix.

warn against reappraisals of the conduct of monetary policy in specific past periods which are based on non ricardian consumers but neglect wage stickiness.

For what concerns the feature of welfare maximizing monetary policy, we conjecture that the optimality of a passive monetary rule, as advocated by Bilbiie (2008) in a sticky prices-flexible wages economy, could be altered by considering a modest degree of wage stickiness. The latter aspect is part of our ongoing research.

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## Appendix

### Log-linearized equilibrium conditions.

This appendix provides a log-linear approximation around a zero inflation steady state to the equilibrium conditions of the model economy. For a detailed derivation see GVL (2007).

Under the assumed functional forms, the Euler equation for Ricardian households takes the log-linear form

$$c_t^o - E_t c_{t+1}^o = -E_t (r_t - \pi_{t+1}) \quad (23)$$

Log-linearization of equations (7) and (9) leads to the dynamic of (real)Tobin's Q

$$q_t = (1 - \beta(1 - \delta)) E_t r_{t+1}^k + \beta E_t q_{t+1} - (r_t - E_t \pi_{t+1}) \quad (24)$$

and its relationship with investment:

$$\eta q_t = i_t - k_{t-1}$$

Equation (11) determines the following log-linear form for consumption of non ricardian agents

$$c_t^{rt} = \frac{(1 - \alpha)}{\mu_p \gamma_c} (l_t + \omega_t) - \frac{1}{\gamma_c} t_t^{rt} \quad (25)$$

where  $\frac{(1-\alpha)}{\mu_p \gamma_c} = \frac{WL}{P} \frac{1}{C}$  is the steady state ratio of labor income to consumption. Since consumption levels are equal at the steady state, it follows that

$$c_t = (1 - \lambda) c_t^o + \lambda c_t^{rt} \quad (26)$$

The stock of capital evolves according to

$$\delta i_t = k_t - (1 - \delta) k_{t-1} \quad (27)$$

Log-linearization of the aggregate resource constraint around the steady state yields

$$y_t = \gamma_c c_t + g_t + (1 - \tilde{\gamma}_c) i_t \quad (28)$$

where  $\tilde{\gamma}_c = \gamma_c + \gamma_g$ . As in shown by Woodford (2003) a log-linear approximation to the aggregate production function is given by

$$y_t = (1 - \alpha) l_t^d + \alpha k_{t-1} \quad (29)$$

Assuming that steady state stock of debt is zero and a steady state balanced government budget, the dynamic of debt around the steady state yields the following law of motion for the stock of debt

$$b_t = (1 + \rho) (b_{t-1} + g_t - t_t) \quad (30)$$

The New Keynesian Phillips Curve (NKPC) is obtained through log-linearization of condition (14) and reads as

$$\pi_t = \kappa_p mc_t + \beta E_t \pi_{t+1} \quad (31)$$

where  $\kappa_p = \frac{(1-\beta\xi_p)(1-\xi_p)}{\xi_p}$  and  $mc_t = (1 - \alpha) w_t + \alpha r_t^k$  is the real marginal cost.

Aggregating firms' profits yields  $D_t = [1 - MC_t \Delta_t] Y_t$ , where  $\Delta_t = \int_0^1 \left( \frac{P_t(z)}{P_t} \right)^{-\theta} dz$  measures equilibrium price dispersion. Since we consider a log-linear approximation around a zero inflation steady state we are allowed to neglect the price dispersion term, as discussed by Schmitt-Grohé and Uribe (2005). Thus, log-deviations of aggregate firm's profits read as  $d_t = y_t - \frac{1}{\mu^p - 1} mc_t$ .

Equations (23) through (31), equation (19) together with the policy rules (16) and (17) determine the equilibrium path of the economy we have outlined.

## Tables

Table 1: Baseline calibration

Parameter	Value	Description
$\beta$	0.99	subjective discount factor
$\lambda$	0.5	share of non Ricardian consumers
$\alpha$	1/3	share of capital
$\delta$	0.025	depreciation rate
$\xi_p$	0.75	Calvo parameter on prices
$\xi_w$	0.75	Calvo parameter on wages
$\theta_p$	6	implies a steady state price mark-up of 0.2
$\theta_w$	6	implies a steady state wage mark-up of 0.2
$\gamma_g$	0.2	steady state share of government purchase
$\tau_\pi$	1.5	Monetary policy response to $\pi$
$\phi_b$	0.33	debt feedback coefficient
$\phi_g$	0.1	public expenditure feedback coefficient
$\rho_g$	0.9	autoregressive coefficient for g process

## Figures

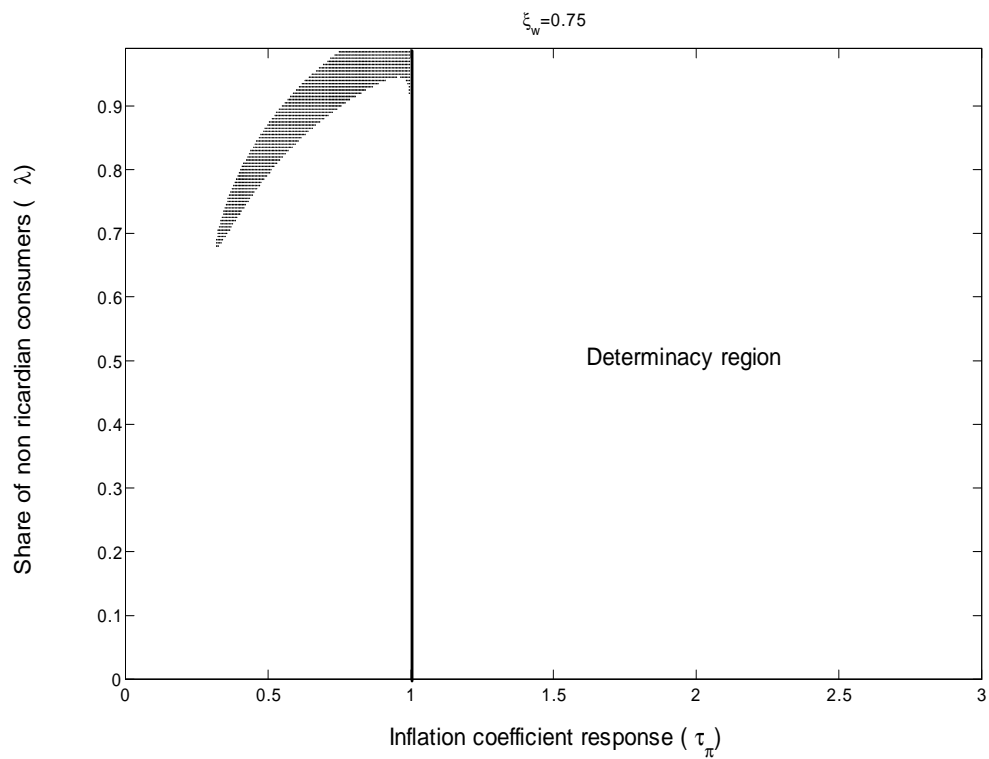


Figure 1: **Determinacy and the Classical Taylor Principle.** Determinacy region under the baseline parameterization. Instability area in black.

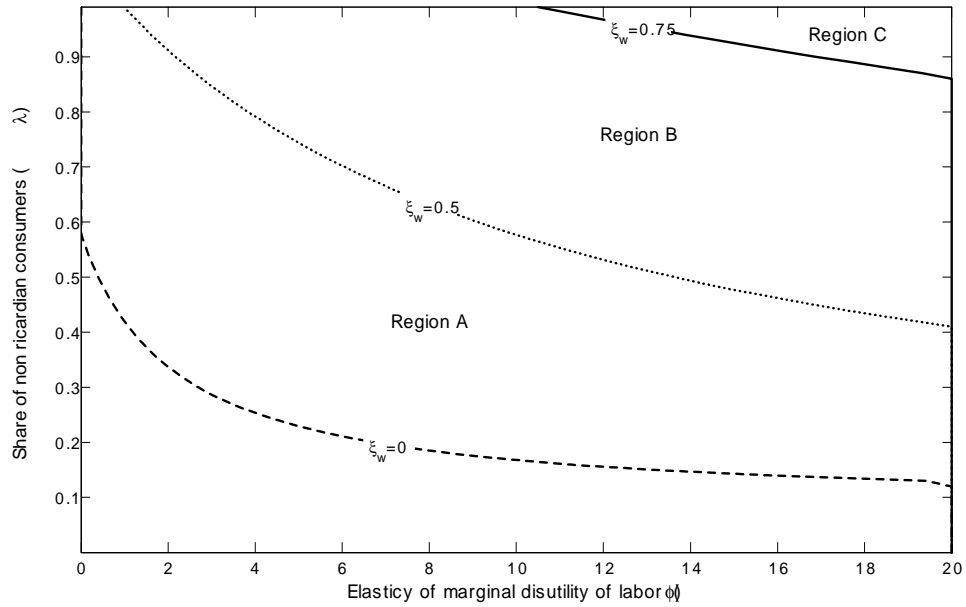


Figure 2: **Determinacy and the value of  $\phi$ .** Indeterminacy regions under alternative degrees of wage stickiness when the monetary authority is assumed to satisfy the Taylor Principle ( $\tau_\pi = 1.5$ ). A+B+C: indeterminacy region under flexible wages; B+C: indeterminacy region when wages have an average duration of two quarters ( $\xi_w = 0.5$ ); C: indeterminacy region when wages have an average duration of four quarters ( $\xi_w = 0.75$ ).

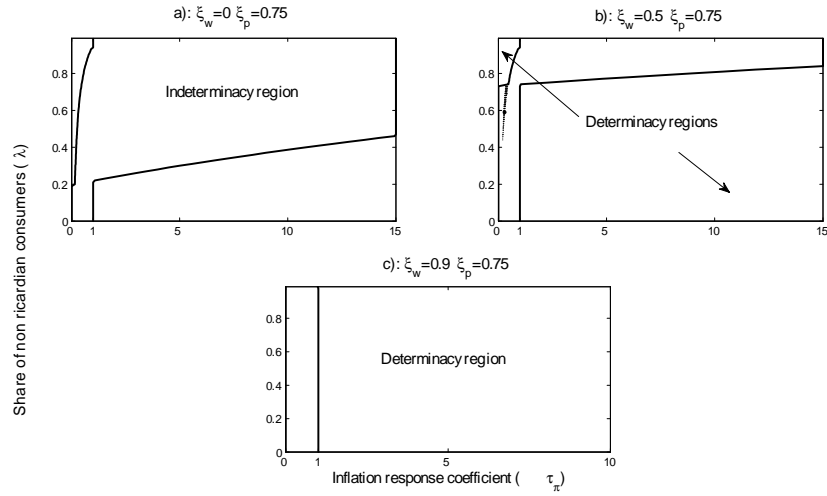


Figure 3: **Taylor Principle and the degree of wage stickiness.** Determinacy and indeterminacy regions under alternative degree of wage stickiness ( $\xi_w$ ). Instability areas in black.

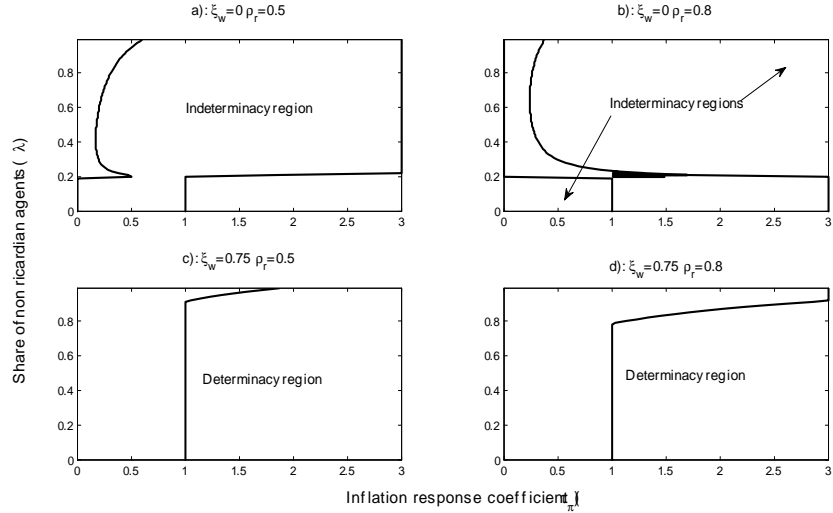


Figure 4: **Determinacy and Interest rate smoothing.** Determinacy and indeterminacy regions under inertial policies and alternative degrees of wage stickiness. Instability areas in black.



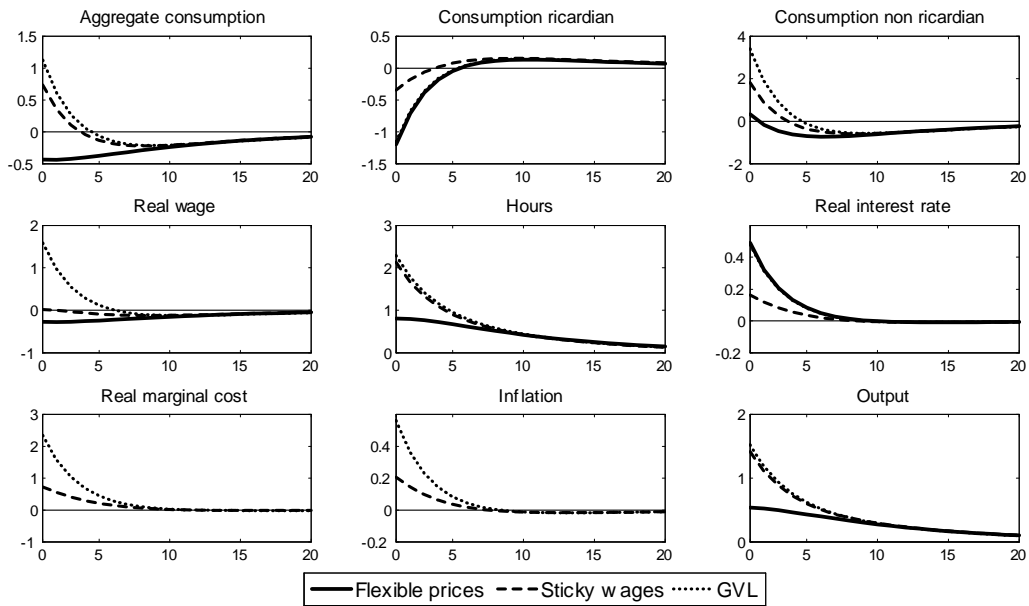


Figure 5: **Government spending shocks and the effect of sticky wages.** Impulse response function to a government spending shock. Solid lines refer to the model with flexible prices; dashed lines to the model with sticky wages; dotted lines to the GVL model. In all cases we set  $\lambda = 0.5$  and  $\phi = 0.2$ .

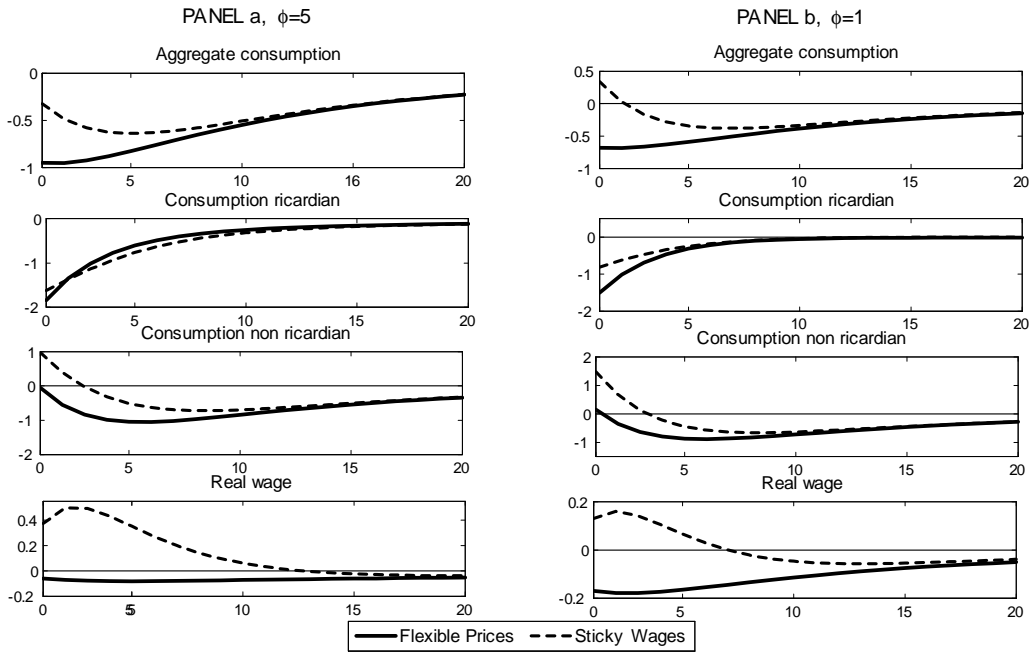


Figure 6: **Government spending shocks and the value of  $\phi$ .** Impulse response function to a government spending shock. Panel a:  $\lambda = 0.5$  and  $\phi = 5$ ; Panel b:  $\lambda = 0.5$  and  $\phi = 1$ . Solid lines refer to the model with flexible prices; dashed lines to the model with sticky wages.

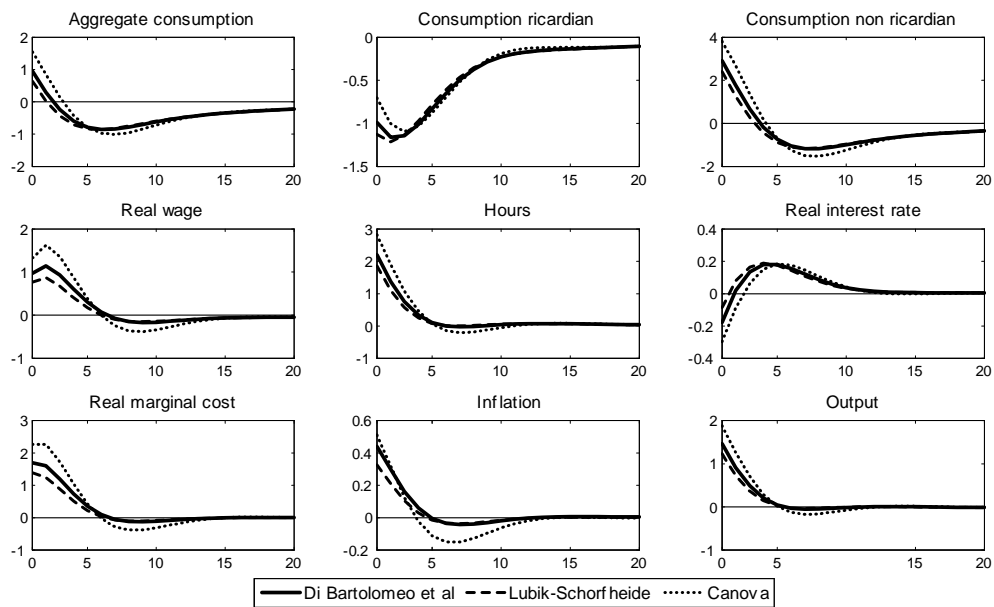


Figure 7: **Monetary policy and the transmission of fiscal shocks.** Impulse response function to a government spending shock. Solid lines refer to the policy rule estimated by Di Bartolomeo et al (2009); dashed lines to the Lubik and Schorfheide (2004) estimates; dotted lines to those by Canova (2009).

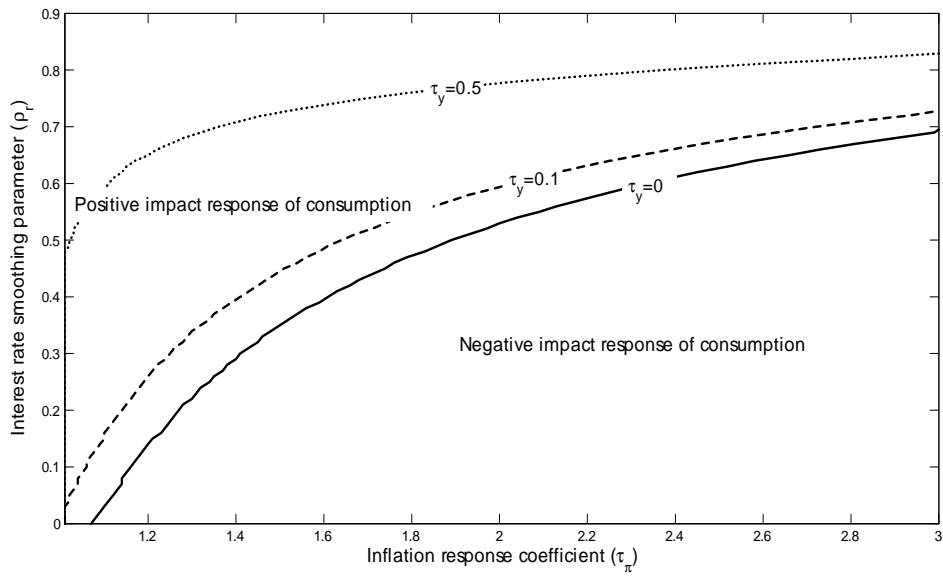


Figure 8: **Monetary policy and impact response of consumption to a government spending shock.** The area above each line depicts the combinations  $(\tau_\pi; \rho_r)$  which lead to a positive impact response of aggregate consumption to a government spending shock. Each line corresponds to a different value of the output response coefficient.

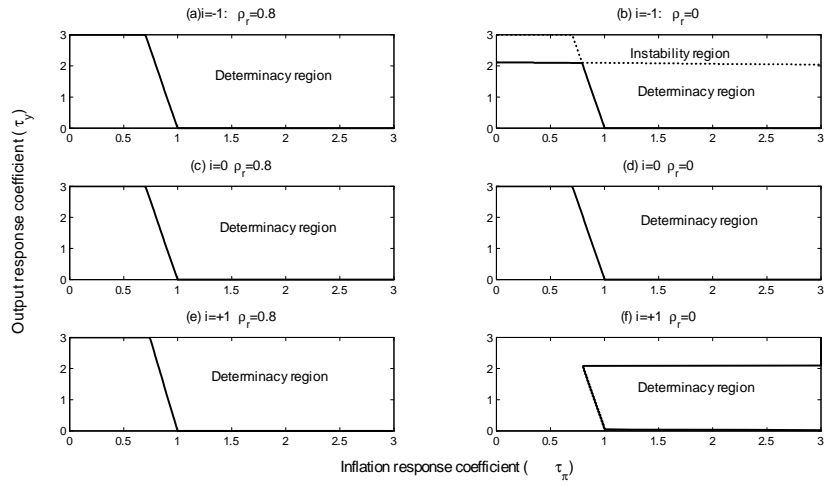


Figure 9: **Taylor Principle and alternative Interest rate rules.** Determinacy and Indeterminacy regions under alternative specifications of the general instrumental rule defined by equation (22).

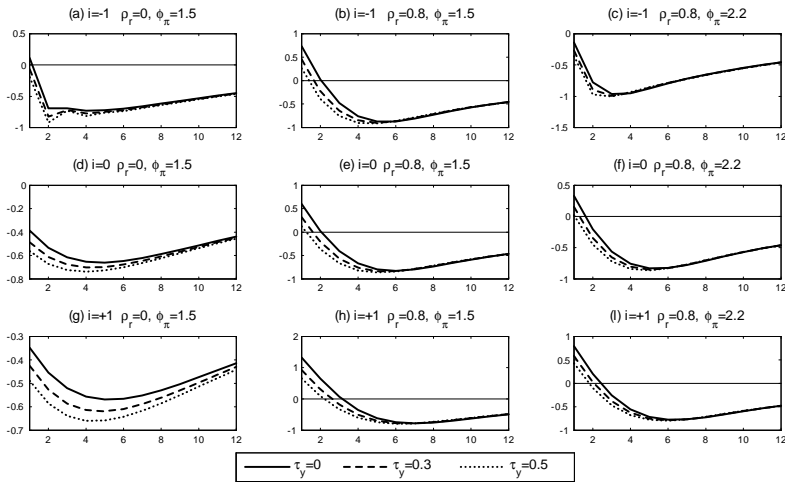


Figure 10: **Impact response of consumption and alternative interest rate rules.** Impulse response functions of aggregate consumption to a government spending shock under alternative specifications of the general instrumental rule defined by equation (22).