Sticky Wages and Rule of Thumb Consumers.

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Abstract

We introduce sticky wages a là Calvo in a model with Non Ricardian or "Rule of Thumb" consumers. With respect to earlier findings, we show that wage stickiness i) restores the Taylor Principle as a necessary condition for equilibrium determinacy; ii) implies that a a rise in consumption in response to an innovation in government spending is not a robust feature of the model. In particular, consumption increases just when the elasticity of marginal disutility of labor supply is low. Results are robust to most of Taylor-type monetary rules used in the literature, including one which responds to wage inflation.

1 Introduction

In recent theoretical contributions the paradigm of the representative agent is contaminated by "rule of thumb" consumers. Agents who consume their available income in each period stand next to, standard, forward-looking agents.

This framework was originally developed by Mankiw (2000) to account for the empirical relationtionship between consumption and disposable income, which seems stronger than that suggested by forward-looking theories of consumer behavior.

Successive contributions introduce rule of thumb, or non ricardian, consumers within the New Keynesian framework.[1] The contemporaneous presence of non ricardian consumers and sticky prices alters the dynamic response of macroeconomic variables to a fiscal shock and has the potentials to influence the effectiveness of monetary policy.

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[1] 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. Simmetrically standard forward looking households are defined as ricardian households. This terminology is due to Galì *et al* (2004).

The latter point is emphasized by Bilbiie (2003) and Dibartolomeo and Rossi (2005). They show that, when the share of rule of thumb consumers over total population is large enough, the interest rate sensitivity of aggregate demand may turn positive. To develop the intuition behind this result, let us consider a model with no capital accumulation and where non ricardian agents work for a constant amount of hours as in Bilbiie (2003). A real rate increase has a counteracting effect on consumption of standard forward looking households and, at the same time, leads to higher labor supply. When the intertemporal elasticity of labor supply is low, small variations in hours worked are accompanied by large fluctuations in the real wage. In this case, the initial increase in the real rate determines a decrease in marginal costs and an increase in profits. If the share of non ricardian consumers is larger than some threshold value, the resulting wealth effect on ricardian consumers is such that aggregate demand increases. The afore-mentioned authors show that, when these conditions verifies, the *Taylor Principle* does not constitute a good monetary policy stance. The Central Bank concerned with avoiding sunspot fluctuations should instead follow and *Inverted Taylor Principle,* i.e. it should engineer a decrease in the real rate of interest in response to a positive inflation variation.

Galì *et al* (2004) also reconsider the validity of the Taylor Principle in the presence of rule of thumb consumers. They point out that when a large share of non ricardian consumers coexists with an extreme degree of price stickiness, the Taylor Principle should, instead, be strenghtened to enforce the determinacy of the rational expectation equilibrium.

The usefulness of the Taylor Principle in an economy where some agents cannot smooth consumption is , thus, seriously questioned.

Turning to the effects of fiscal shocks Galì Valles and Lopez-Salido (2003, GVL hereafter) find that rule of thumb consumers constitute a potential solution to the so called *Government Spending Puzzle*. Empirical evidence on U.S. data suggests that private consumption does not decrease after a government purchase shock. Blanchard and Perotti (2002) and GVL, *inter alia,* estimate a positive and significant relationship between private consumption and government spending.

Nevertheless, standard DSGE models predict that a rise in government purchases will have a contractionary effect on consumption. The reason is that a larger, improductive, government expenditure generates a negative wealth effect which results in lower consumption by forward-looking households.

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.

GVL show that rule of thumb behavior help delivering a positive response of aggregate consumption to an innovation in government spending, when the latter is partly financed by debt issuance.

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) find that the response of the real wage to a fiscal shock is negative, while Blanchard and Perotti and Fatas and Mihov (2002) document a positive but limited response.

In this paper we introduce Calvo nominal wage stickiness in a New Keynesian model with rule of thumb consumers. We reconsider the effects of rule of thumb consumers on determinacy conditions and on the response of the economy after a fiscal innovation.

We show that nominal wage stickiness : i) restores the Taylor Principle as a necessary condition for equilibrium determinacy under a large range of parameter values; ii) implies that a rise in aggregate consumption in response to a government spending innovation emerges just for *ad hoc* parametrizations.

With respect to i) we point out that nominal wage stickiness dampens real wage fluctuations associated to variations in hours and, through this channel, strongly limits the likelihood of a positive real rate elasticity of aggregate demand. In this case the Taylor Principle returns a necessary condition for equilibrium determinacy. The degree of wage stickiness required for this result to hold is lower than that suggested by available empirical estimates. Thus, once price-wage rigidities are both taken into account, determinacy regions in the parameters space are similar to those delivered by a representative agent economy.

With respect to ii) we show that nominal wage stickiness prevents the large increase in the real wage in the aftermath of a government spending shock which affects the GVL's model. For empirically plausible values of parameters, the positive response of aggregate consumption to an innovation in government spending vanishes. Government purchase shocks are coupled with a raise in aggregate consumption just in the case in which agents suffer a low cost of supplying labor in terms of utility. In such a case variations in hours worked are enough to boost consumption of ricardian agents, and to drive up aggregate consumption.

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

In sum our paper shows that once nominal wage stickiness is considered in a New Keynesian economy with rule of thumb consumers, standard results concerning determinacy conditions are restored. Further it shows that a rise in aggregate consumption in response to a government spending shock is not a robust feature of the model.

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 verifies the robustness of the results to alternative interest rate rules. Section 6 concludes.

2 The model

2.1 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:

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

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

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

Intermediate inputs $Y_t(z)$ are produced by a continuum of size one of monopolistic firms which share the following technology:

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

where $0 < \alpha < 1$ is the share of income which goes to capital in the long run, $K_{t-1}\left(z\right)$ is the time t capital service hired by firm z, while $L_t\left(z\right)$ is the time t quantity of the labor input used for production. The latter is defined as $L_t = \left(\int_0^1 L_t^{j\frac{\theta_w - 1}{\theta_w}} dj \right)^{\frac{\theta_w}{\theta_w - 1}}$ with $\theta_w > 1$. Firm's z demand for labor type j and the aggregate wage index are respectively

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

The nominal marginal cost is given by

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

where R_t^k is the rental rate of capital in nominal terms.

Price setting. We assume that firms set prices according to the mechanism spelled out in Calvo (1983). Firms in each period have a chance $1 - \xi_p$ to reoptimize their price. A price setter z takes into account that the choice of its time t nominal price, $\widetilde{P}_t$, might affect not only current but also future profits. The associated first order condition is:

$$E_t \sum_{s=0}^{\infty} \left(\beta \xi_p \right)^s \nu_{t+s} P_{t+s}^{\theta} Y_{t+s} \left[\widetilde{P}_t - \mu^p P_{t+s} MC_{t+s} \right] = 0 \tag{2}$$

which can be given the usual interpretation.[2] 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.

[2] ν_t is the value of an additional dollar for a ricardian household. As it will be clear below, is the lagrange multiplier on ricardian househols nominal flow budget constraint.

2.2 Labor market

The description of the labor market follows Colciago *et al* (2006). We assume a continuum of differentiated labor inputs indexed by j. Wage-setting decisions are taken by a continuum of unions. More precisely union j monopolistically supplies labor input j on labor market j. Union j takes as given firms' demand for its labor service and sets the nominal wage, W_t^j, in order to maximize a weighted average of both agents' utilities.[3] As in Schmitt-Grohé and Uribe (2004a), agent i supplies all labor inputs. Further, following GVL, we assume that agents are distributed uniformly across unions.[4] Firms allocate labor demand on the basis of the relative wage, without distinguishing according to household types. This implies that once the union has fixed the nominal wage, aggregate demand of labor type j is spreaded uniformly between all households. In other words, individual levels of employment and labor income are the same across households. The latter is given by $L_t^d \int_0^1 W_t^j \left(\frac{W_t^j}{W_t}\right)^{-\theta_w} dj \; = W_t L_t^d$, where L_t^d is aggregate labor demand.[5]

2.3 Households

There is a continuum of households on the interval $[0,1]$. As in GVL, households in the interval $[0,\lambda]$ cannot access financial markets and do not have an initial capital endowment. The behavior of these agents is characterized by a simple rule of thumb: they consume their available labor income in each period. The rest of the households on the interval $(\lambda,1]$, instead, is composed by standard ricardian households who have access to the market for physical capital and to a full set of state contingent securities. We assume that Ricardian households hold a common initial capital endowment. The period utility function is common across households and it has the following separable form

$$U_t = u\left(C_t\left(i\right)\right) - v\left(L_t\left(i\right)\right)$$

where $C_t(i)$ is agent *i's* consumption and $L_t(i)$ are labor hours. It follows that the total number of hours allocated to the different labor markets must satisfy the time resource constraint $L_t\left(i\right) = \int_0^1 L_t^j\left(i\right) dj$

[3] The union objective function is descrived below as, at this stage, we just provide a description of the labor market structure.

[4] This implies that a share λ of the associates of each union is composed by non ricardian agents.

[5] 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.

Ricardian households. Ricardian Households' time t nominal flow budget reads as

$$\begin{aligned} & P_t\left(C_t^o+I_t^o\right)+\left(1+R_t\right)^{-1} B_t^o+E_t \Lambda_{t, t+1} X_{t+1} \\ \leq \quad & X_t+W_t L_t^d\ +R_t^k K_{t-1}^o+B_{t-1}^o+P_t D_t^o-P_t T_t^o \end{aligned} \tag{3}$$

we assume that ricardian agents have access to a full set of state contingent assets. More precisely, in each time period t, consumers can purchase any desired state-contingent nominal payment X_{t+1} in period *t+1* at the dollar cost $E_t \Lambda_{t,t+1} X_{t+1}$. $\Lambda_{t,t+1}$ denotes a stochastic discount factor between period $t+1$ and t. $W_t L_t^d$ denotes 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. $P_t D_t^o$ are dividends due from the ownership of firms, while B_t^o is the quantity of nominally riskless bonds purchased in period t at the price $\left(1+R_t\right)^{-1}$and paying one unit of the consumption numeraire in period *t+1*. $P_t T_t^o$ represent nominal lump sum taxes. As in GVL, the household's stock of physical capital evolves according to:

$$K_t^o=(1-\delta) K_{t-1}^o+\sigma\left(\frac{I_t^o}{K_{t-1}^o}\right) K_{t-1}^o \tag{4}$$

where δ 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 σ 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 istantaneous utility subject to constraints (3) and (4). ν_t and Q_t denote the Lagrange multipliers on the first and on the second constraint respectively. $\beta=\frac{1}{1+\rho}$ is the discount factor, where ρ is the time preference rate. The first order conditions with respect to C_t^o, I_t^o, B_t^o, K_t^o, X_{t+1} are

$$u_c\left(C_t^o\right)=\nu_t P_t \tag{5}$$

$$\frac{1}{\phi'\left(\frac{I_t^o}{K_{t-1}^o}\right)}=q_t \tag{6}$$

$$\frac{1}{\left(1+R_t\right)}=\beta E_t \frac{\nu_{t+1}}{\nu_t} \tag{7}$$

$$Q_t=E_t\left\{\Lambda_{t, t+1}\left[R_{t+1}^k+Q_{t+1}\left((1-\delta)-\phi'\left(\frac{I_{t+1}^o}{K_t^o}\right) \frac{I_{t+1}^o}{K_t^o}+\phi\left(\frac{I_{t+1}^o}{K_t^o}\right)\right)\right]\right\} \tag{8}$$

$$\Lambda_{t, t+1}=\beta \frac{\nu_{t+1}}{\nu_t} \tag{9}$$

where $q_t = \frac{Q_t}{P_t}$ is the real shadow value of installed capital, i.e. Tobin's Q. Substituting (5) into (9) we obtain the definition of the stochastic discount factor

$$\Lambda_{t,t+1} = \beta \frac{u_c\left(C^o_{t+1}\right)}{P_{t+1}} \frac{P_t}{u_c\left(C^o_t\right)}$$

while combining (9) and (7) we recover the following arbitrage condition on the asset market

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

Non ricardian households. Non ricardian households maximize period utility subject to the constraint that they have to consume available income in each period, that is

$$P_t C^{rt}_t = W_t L^d_t - P_t T^{rt}_t \tag{10}$$

As in GVL we let lump sum taxes (transfers) paid (received) by non ricardian households differ by those paid by ricardian.

2.4 Wage Setting

Nominal wage rigidities are modeled according to the Calvo mechanism used for price setting. In each period a union faces a constant probability $1 - \xi_w$ of being able to reoptimize the nominal wage. We follow GVL, 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 λ, respectively. The union objective function is

$$E_t \sum_{s=0}^{\infty} \left(\xi_w \beta\right)^s \left\{ \left[(1-\lambda)\, u\left(c^o_{t+s}\right) + \lambda u\left(c^{rt}_{t+s}\right)\right] + v\left(L^d_{t+s} \int_0^1 \left(\frac{W^j_{t+s}}{W_{t+s}}\right)^{-\theta_w} dj \right) \right\}$$

The FOC with respect to $\widetilde{W}_t$ is

$$E_t \sum_{s=0}^{\infty} \left(\beta \lambda_w\right)^{t+s} \Phi_{t,t+s} \left\{ \left[\lambda \frac{1}{MRS^{rt}_{t+s}} + (1-\lambda)\frac{1}{MRS^o_{t+s}}\right] \frac{\widetilde{W}_t}{P_{t+s}} - \mu^w \right\} = 0 \tag{11}$$

where $\Phi_{t,t+s} = v_L\left(L_{t+s}\right) L^d_{t+s} W^{\theta_w}_t$ and $\mu^w = \frac{\theta_w}{(\theta_w - 1)}$ is the, constant, wage mark-up in the case of wage flexibility. MRS^{rt}_{t+s} and MRS^o_{t+s} are the marginal rates of substitution between labor and consumption of non ricardian and ricardian agents respectively. Notice that when wages are flexible (11) becomes

$$\frac{W_t}{P_t} = \mu^w \left[\lambda \frac{1}{MRS^{rt}_t} + (1-\lambda)\frac{1}{MRS^o_t}\right]^{-1} \tag{12}$$

which is identical to the wage setting equation in GVL.

2.5 Government

The Government nominal flow budget constraint is

$$P_t T_t + (1 + R_t)^{-1} B_t = B_{t-1} + P_t G_t \tag{13}$$

where $P_t G_t$ is nominal government expenditure on the final good. As in GVL we assume a fiscal rule of the form

$$t_t = \phi_b b_{t-1} + \phi_g g_t \tag{14}$$

where $t_t = \frac{T_t - T}{Y}$, $g_t = \frac{G_t - G}{Y}$ and $b_t = \frac{\frac{B_t}{P_t} - \frac{B_{t-1}}{P_{t-1}}}{Y}$. g_t is assumed to follow a first order autoregressive process

$$g_t = \rho_g g_{t-1} + \varepsilon_t^g \tag{15}$$

where $0 \leq \rho_g \leq 1$ and ε_t^g is a normally distributed zero-mean random shock to government spending.[6]

2.6 Monetary Policy

An interest rate-setting rule is required for the dynamic of the model to be fully specified. We focus on the rule analyzed by GVL which features the central bank setting the nominal interest rate as a function of current inflation according to the following log-linear rule

$$r_t = \tau_\pi \pi_t \tag{16}$$

where $r_t = \log \frac{(1+R_t)}{1+\rho}$ and $\pi_t = \log \frac{P_t}{P_{t-1}}$. In standard sticky price models with no endogenous investment, as in Woodford (2003) or Galì (2002), rule (16) ensures local uniqueness of a rational expectation equilibrium if it satisfies the *Taylor Principle*, i.e. if $\tau_\pi > 1$.

2.7 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

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

[6] A sufficient condition for non explosive debt dynamics is

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

which is satisfied if

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

I assume this condition is satisfied throughout.

2.8 Market Clearing

The market clearing conditions in the goods market and in the labor market imply

$$\begin{array}{lll} Y_t = C_t + G_t + I_t; & Y_t^s(z) = Y_t^d(z) = \left(\frac{P_t(z)}{P_t}\right)^{-\theta_p} Y_t & \forall z. \\ L_t = L_t^d; & \left(L_t^j\right)^s = \left(L_t^j\right)^d = \left(\frac{W_t^j}{W_t}\right)^{-\theta_w} L_t & \forall j. \end{array}$$

where $L_t^d = \int_0^1 L_t(z)\, dz$ and $\left(L_t^j\right)^d = \int_0^1 L_t^j(z)\, dz$.

2.9 Steady State

As in GVL, we assume that steady state lump sum taxes are such that steady state consumption levels are equalized across agents. Firm *i's* cost minimization implies

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

where

$$\frac{K}{Y} = \frac{\alpha}{\mu^p(\rho+\delta)}$$

Since the ratio $\frac{G}{Y} = \gamma_g$ is, by assumption, exogenous, we can determine the steady state share of consumption on output, γ_c, as follows

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

which, as noticed by GVL, is independent of λ. In what follows it will prove useful to know $\frac{W}{P}\frac{L}{C}$, which equals

$$\frac{W}{P}\frac{L}{C} = \frac{(1-\alpha)}{\mu^p}\frac{Y}{L}\frac{L}{C} = \frac{(1-\alpha)}{\mu^p\gamma_c}$$

3 The Log-linearized model.

To make our results readily comparable to those in GVL we assume the same period utility function considered in their work:

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

which features a unit intertemporal elasticity of substitution in consumption and a constant elasticity of the marginal disutility of hours $v_{LL} = \phi$.[7] In what follows lower case letters denote log-deviations from the steady state values. The

[7] The selected period utility belong to the King-Plosser-Rebelo class and leads to consant steady hours.

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 GVL 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, the real wage schedule and the effect of economic activity on the real wage.

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

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

where $mrs_t^A = \lambda mrs_t^{rt} + (1-\lambda) mrs_t^o$ is a weighted average of the log-deviations between the marginal rates of substitution of the two agents. 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

$$\pi_t^w = \beta E_t \pi_{t+1}^w - \kappa_w \mu_t^w \tag{17}$$

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 union impose over the average marginal rate of substitution.[8] Due to the assumption that unions maximize a weighted average of agents' utilities, the wage inflation curve has a standard form. Equation (17) allows to obtain the log-deviation of time t real wage, which plays a prominent role in the determination of non ricardian agents consumption, as follows

$$w_t = \Gamma \left[w_{t-1} + \beta \left(E_t w_{t+1} + E_t \pi_{t+1} \right) - \pi_t \right] + \Gamma \kappa_w \left(\phi l_t + c_t \right) \tag{18}$$

[8] As pointed out by Schmitt-Grohe and Uribe (2004a), the coefficient κ_w is different form that in Erceg et al (2000), which is the standard reference for the analysis of nominal wage stickiness.The reason is that we are assuming that agents provide all labor inputs. In the more standard case in which each individual is the monopolistic supplier of a given labor input, κ_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 $\Gamma = \frac{\xi_w}{(1+\beta\xi_w^2)}$. Γ determines both the degree of forward and backward lookingness.[9] Today's average real wage is a function of its lagged and expected value, expected and current inflation. The term $\phi l_t + c_t$ represents the average real wage that would prevail in the case of wage flexibility.

Substituting (27) into (18) we obtain:

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

where $\Psi = \Gamma\frac{\kappa_w}{(1-\alpha)}\phi$ determines the effect on the real wage due to changes in the level of real activity.

Comparative statics. $\frac{\partial\Gamma}{\partial\xi_w} > 0$: a longer average duration of wage contracts does not have a clear cut effect on real wage inertia. As ξ_w gets larger both forward and backward lookingness increase. $\frac{\partial\Psi}{\partial\phi} > 0$: the more elastic is the marginal disutility of labor, i.e. the higher is ϕ, the higher is the sensitivity of wages to an increase in economic activity. $\frac{\partial\Psi}{\partial\xi_w} < 0$: the higher is average duration of wage contracts, i.e. the higher is ξ_w, the lower is the sensitivity of wages to an increase in economic activity.

Intuition goes as follows. A higher ξ_w implies that the nominal wage will be newly reset on a limited number of labor markets, thus the previous period average wage has a stronger influence on today's. At the same time those unions which optimally reset their wage will attach a higher weight on expected future variables. The parameter Ψ determines the size of the variation in real wage associated with a given variation in real economic activity. This is jointly determined by the probability that wages cannot be changed in a given period, ξ_w, and the elasticity of the marginal disutility of labor, ϕ.

Woodford and Rotemberg (1997) report evidence suggesting that the output elasticity of real wage is in a neighborhood of 0.3.

Figure 1 plots Ψ as a function of ϕ for alternative degrees of wage stickiness assuming the values $\beta = 0.99$ and $\alpha = \frac{1}{3}$. Empirical estimates suggest that wages have an average duration of an year ($\xi_w = 0.75$). In this case, a value of Ψ consistent with the estimates in Rotemberg and Woodford (1997) is obtained by setting ϕ close to 5.

In a model with a frictionless labor market this would lead to an intertemporal elasticity of substitution in labor supply equal to 0.2, which is in line with the micro-evidence in Card (1991) and Pencavel (1986). Thus, we obtain a output sensitivity of real wage consistent with the estimates using empirically plausible values of ϕ and ξ_w.

This is not the case under wage flexibility. When $\xi_w = 0$ 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 GVL. In order to be consistent with the afore-mentioned evidence on the output elasticity of real wage GVL set ϕ

[9] The effect of discounting on the forward looking component is quantitatively negligible.

equal to 0.2. This value is, however, far from consistent with the microeconomic evidence on the elasticity of labor supply and from standard calibration of preferences.

4 Results

4.1 Calibration

We calibrate the parameters of the model since the analysis of equilibrium determinacy and equilibrium dynamics that follow draws on numerical results. The time unit is meant to be a quarter. In the baseline parametrization 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). α and β assume the standard values of $\frac{1}{3}$ and 0.99 respectively. Table 1 reports the output sensitivity of real wage Ψ as a function of ϕ. In column 2 we consider the baseline calibration for wage stickiness, while in column 4 we evaluate Ψ under the limiting case of wage flexibility.

Table 1 shows that, under the baseline calibration for wage stickiness, setting $\phi = 4.84$ allows to match the output elasticity of real wage reported by Rotemberg and Woodford (1997), thus we take this value as the baseline. However, to evaluate the dependence of the model's implications on the elasticity of the marginal disutility of labor, we consider two other values of ϕ beside the baseline. The first, $\phi = 0.2$, corresponds to the value employed by GVL, the second $\phi = 1$ is chosen because commonly employed in the literature. The table, consistently with the discussion in the previous section, points out that when standard values are assigned to ϕ, the flexible wage scenario ($\xi_w = 0$) leads to extremely high output sensitivity of real wage.

Table 1: Output sensitivity of real wage as a function of the elasticity of labor disutility and the calvo parameter on wages.

	Ψ		Ψ
ϕ=0.2; ξ_w=0.75	0.011	ϕ=0.2; ξ_w=0	0.3
ϕ=1; ξ_w=0.75	0.055	ϕ=1; ξ_w=0	1. 5
ϕ=4.84; ξ_w=0.75	0.300	ϕ=4.84; ξ_w=0	7. 26

The baseline value for the share of non ricardian consumers, λ, 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 2, and the reader can refer to the references reported in GVL for empirical evidence supporting them. However, it is worth mentioning that in the baseline calibration τ_π is set to 1.5. Thus monetary policy is assumed to satisfy the standard Taylor Principle.

Table 2: Baseline calibration

Parameter	Value	Description
β	0.99	subjective discount factor
λ	0.5	share of non Ricardian consumers
α	1/3	share of capital
δ	0.025	depreciation rate
ξ_p	0.75	Calvo parameter on prices
ξ_w	0.75	Calvo parameter on wages
θ_p	6	implies a steady state price mark-up of 0.2
θ_w	6	implies a steady state wage mark-up of 0.2
γ_g	0.2	steady state share of government purchase
τ_π	1.5	Monetary policy response to π
ϕ_b	0.33	debt feedback coefficient
ϕ_g	0.1	public expenditure feedback coefficient
ρ_g	0.9	autoregressive coefficient for g process

4.2 Determinacy

In this section we ask the following questions: what are the combinations of τ_π and λ which result into a determinate equilibrium? How are they affected by the wage stickiness parameters?

Result 1. Determinacy and the Taylor Principle. The Taylor Principle is a necessary and sufficient condition for equilibrium determinacy under a large range of parameter values

When wage stickiness is considered, the *Inverted Taylor Principle* ceases to be a relevant concept for determinacy.

To develop the intuition behind this result let me consider the thought experiment provided by Bilbiie (2005), where wages are assumed to be perfectly flexible.

Suppose that the level of inflation starts increasing without any change in fundamentals that could justify it.

To the extent that the central bank follows the Taylor Principle, the real interest rate increases in the aftermath of the sunspot in inflation. This has a contractionary effect on consumption of ricardian agents. Due to lower demand, some firms will fix a lower price, while those firms who cannot adjust their price will reduce labor demand, putting a downward pressure on the real wage.

If ϕ is large enough, small variations in hours are accompanied by large variations in the real wage. As a result real marginal costs decrease and, thus, there is a potential increase in profits.

The latter determines a positive wealth effect on consumption of ricardian consumers, magnified by the presence of non ricardian consumers, which drives up aggregate demand. The sunspot can, thus, be ex-post rationalized through the positive relationship between inflation and output implied by the NKPC.

Notice that an interest rate rule that satisfied the *Inverted Taylor Principle*, would lead to a fall in profits, making the initial increase in inflation non compatible with a rational expectation equilibrium.

How does wage stickiness alter the adjustment process just described?

The key point is that wage stickiness dampens variation in the real wage associated to changes in hours in the same ways as it dampens variation in the real wage due to changes in economic activity.

As a result real marginal costs do not decrease as they would if wages were flexible. In this case, the wealth effect produced by the, potential, increase in profits does not offset the substitution effect exerted on demand of ricardian consumers by the initial real rate increase. This prevents the increase in demand that could ex-post render the sunspot in inflation compatible with a rational expectation equlibrium.

Turning to the second of our questions, we show that the degree of wage stickiness necessary to restore the validity of the Taylor Principle is not just compatible with the estimates, but very small. Figure 3 depicts indeterminacy areas in the case of alternative degrees of wage stickiness. In Panel *a* wages are perfectly flexible. When $\lambda \geq 0.2$ there are determinate equilibria which are compatible with an inflation response coefficient $\tau_\pi < 1$.

However, when the average duration of wage contracts reaches 2 quarters (panel *b*), $\tau_\pi < 1$ implements determinate equilibria just if $\lambda > 0.7$. Since the latter values is well above the estimates of the importance of rule of thumb behavior reported above, it can be regarded as a case of minor empirical relevance. Panel *c* shows, as expected, that our results are not altered when the average duration of wage contracts is increased to 10 quarters.

Finally, notice that, under the baseline parametrization for other parameters, the Taylor Principle is necessary and sufficient for determinacy 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 consider to be plausible in empirical works.

As in Galì et al (2004), we find that when strong price stickiness coexists with a large share of non ricardian consumers the Taylor Principle needs to be strenghtened to enforce a unique rational expectation equilibrium. However, we raise an important qualification with respect to their work. Namely, that when wage stickiness is brought into the picture the Taylor Principle remains a valid criterion to avoid sunspot fluctuations when the relevant parameters (ξ_w, ξ_p, λ) assume values compatible with the empirical estimates.

While factors such as firm specific capital or trend inflation[10] may effectively invalidate the goodness of the Taylor Principle as a criterion for the conduct of monetary policy, our analysis shows that this is not the case for rule of thumb consumers.

Below we argue that this conclusion holds for most of the interest rate rules considered in the literature.

[10] See Sveen and Weinke (2005) and Ascari and Ropele (2006) respectively.

4.3 Consumption and Government Spending Shocks.

Figure 4 depicts the response of key variables to a government spending shock in the case of the baseline parametrization.[11]

Result 2. Impact response of aggregate consumption. Aggregate consumption decreases in the aftermath of a, partially debt financed, government spending shock.

Two forces act in the direction of reducing consumption of ricardian consumers. The first one is the negative wealth effect determined by the government purchase shock, while the second one is due to the positive response of the real interest rate to the shock. In fact, although wage stickiness dampens the variations in real marginal costs, and through this channel those of inflation, the response of monetary policy is such that the real interest goes up. To analyze the overall effect on aggregate consumption, we have to consider the effect induced on c^{rt} by the unexpected rise in Government spending. Sticky wages prevent the large increase in real wage affecting the GVL's model. This, jointly with a less prominent rise in hours worked, implies that consumption of non ricardian consumers does not grow as much as required to determine a positive impact response of aggregate consumption.

In what follows we assess the sensitivity of result 2 to alternative parametrizations of the elasticity of marginal disutility of labor and to the share of non ricardian consumers. In Figure 5 we evaluate the sensitivity to ϕ. Dotted lines correspond to the value chosen by GVL, dashed lines to the unit elasticity case, while solid lines to the baseline value.

Result 3. Impact response of aggregate consumption and ϕ. The effect of a Government spending shock on private consumption is positive when the elasticity of marginal disutility of labor, ϕ, is low.

Consider the case in which ϕ=0.2. Both, the impulse response of c^{rt} and c^o are favorable to a positive impact variation of aggregate consumption with respect to the baseline case.

Beside determining a modest elasticity of real wage with respect to output, a low value of ϕ implies that agents require a limited wage change in the face of a labor demand variation. Nevertheless, the increase in hours more than compensates for the negligible variation in the real wage, and consumption of non ricardian agents responds more markedly than in other cases. Further, the slight inflationary pressure determines a limited monetary tightening, which results in a small reduction in ricardian agents consumption.

However, as the elasticity of the marginal disutility of labor increases and, importantly, the sensitivity of the real wage with respect to output approaches the value supported by the evidence, the dynamic of variables is such that aggregate consumption diminishes.

[11] We used DYNARE to solve the system of dynamic equations constituting the model. The software is available at http://www.dsge.net/.

Finally, we assess the role played by the share of non ricardian consumers, λ. A clear result emerges from figure 6.

Result 4. Aggregate consumption and λ. Aggregate consumption shows a positive response to a government spending shock for large values of the share, λ, of non ricardian consumers.

Figure 6 makes clear that aggregate consumption shows a positive, and mildly persistent, response for values of the share on non ricardian consumers which are above the upper interval of empirical estimates. As in GVL the effect of the spending shock on output is increasing in the share of non ricardian consumers. This implies also that the effect on labor demand and on the real wage are positive function of λ. The pattern of the real wage is transmitted to price inflation. Since monetary policy obeys to the Taylor Principle, the real rate grows. For this reason consumption of ricardian consumers is lower the higher the share of non ricardian consumers. This effect counterbalances the increase in c^{rt}, which, instead, is a positive function of λ.

5 Robustness to alternative interest rate rules.

In this section we discuss whether Results 1 and 2 are robust to simple variant of the Taylor rules proposed in the literature.

We consider rules which are specialization of the, general, instrumental rule

$$r_t = \rho_r r_{t-1} + \tau_\pi E_t \pi_{t+i} + \tau_y E_t y_{t+i} \tag{20}$$

When $i = -1$, (20) 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 specification mentioned we consider the case of inertia, with $\rho_r = 0.5$.

Determinacy. Figure 7 depicts indeterminacy regions for each of the specification we consider. A key result is stated in the following.

Result 5. Determinacy and non ricardian consumers. Under the majority of Taylor-type interest rate setting rules considered in the literature, the determinacy and indeterminacy regions for the model with non ricardian consumers featuring price-wage stickiness are similar to those identified for a representative agent economy.

We start by analyzing non-inertial cases. In panel d we extend the baseline monetary rule analyzed earlier to allow for an output gap response. The determinate region can be labelled as standard in the following sense. Determinacy always obtains when $\tau_\pi > 1$, i.e. if the Taylor principle is satisfied. However, as in the standard model, values of τ_π lower or equal to 1 are admissible as long as the central bank compensates by responding to the output gap. Panel b

depicts the backward looking specification. In spite of rule of thumb consumers and capital accumulation, determinacy regions are once again similar to those obtained for a standard model. As in Bullard and Mitra (2002), the panel is divided into two regions by the horizontal line $\tau_y = 2$. Each of the resulting region is further divided into two sub-regions. Below the line $\tau_y = 2$ we can find the standard (in the sense provided above) regions of determinacy (right) and indeterminacy (left). Moving above the afore-mentioned line there is, on the left, a non standard indeterminacy region. It is non standard not because it is different from that we would obtain setting $\lambda = 0$, but because determinacy obtains if the inflation coefficient is below a certain threshold, and because the trade off between $\tau_\pi$and τ_y is reversed, i.e. higher value of inflation response should be compensated by lower aggressiveness on output. Finally the north east area features a set of unstable equilibria.

The forward looking rule is depicted in case *f.* Determinacy region 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 and should be implemented with care.

Panels on the left hand side of the picture suggest that nominal interest rate inertia makes indeterminacy less likely, no matter the rule followed by the central bank. As in the standard model, inertia reduces the threshold value of τ_π required for determinacy. In the cases depicted, where $\rho_r = 0.5$, determinacy obtains as long as $\tau_\pi > 0.5$. Notice that Increasing ρ_r to 1 rules out indeterminate equilibria.[12] Increasing the size of rule of thumb consumers does not determine variations of indeterminate regions in the contemporaneous and forward looking case. It affects, instead, the backward looking case. More precisely indeterminacy regions in the inertial case are similar to those obtained for the non inertial case.[13]

Consumption and Government Spending Shocks. Figure 8 reports the response of aggregate consumption to a government spending shock under the various specifications of the general rule (20) we have analyzed. The response of the central bank to price inflation is kept at its baseline value, while we report impulse response functions for three different specification of τ_y. We emphasize the following.

Result 6. Aggregate consumption and monetary rules. Backward looking monetary rules are more likely than contemporaneous and forward looking rules to deliver a positive impact response of aggregate 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.

[12] Needless to say this is true as long as either τ_π or τ_π are larger than zero.

[13] The interested reader can find a detailed analysis of alternative intrerest rate rules at the URL: tttp://dipeco.economia.unimib.it/persone/colciago, where I also consider a rule which reacts to wage inflation. In this case a necessary condition for determinacy is $\tau_p + \tau_w > 1$, where τ_w is the wage inflation coefficient response. It should not be, by now, surprising that this is equivalent to the condition which holds in a model without non ricardian consumers.

The reason for which a backward looking rule helps obtaining a positive impact response is straightforward. If the central bank responds to lagged variables, monetary conditions are unchanged during the period in which the shock hits the economy, i.e. there is no positive impact increase in the real rate as under the contemporaneous and the forward looking rule. This favours a mild reduction in consumption of ricardian consumers, while that of non ricardian is positively affected by the increase in hours worked and the real wage. However, as the effects of the shock are transmitted to inflation and output, the variation in the real rate of interest determines a reduction in level of employment, which drives c^{rt} below the steady state level and at the same time causes a further reduction in c^{o}. These effects are mirrored in the dynamic pattern of aggregate consumption, which exhibits a positive response on impact, but lacks of persistence. Notice that this stands in sharp contrast with what happens if the central bank follows, for example, a contemporaneous rule, where aggregate consumption decreases smoothly after the government spending shock (panel d). The contemporaneous and the forward looking rule do not, instead, differ relevantly for what concerns the likelihood of delivering a positive impact response of consumption, no matter whether we consider an inertial component in interest rate setting.

Reacting to output deviation determines a less marked increase in production in the aftermath of the shock, containing the variation in hours worked and, thus, in consumption of non ricardian consumers.[14]

6 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 be taken into account that labor markets and the wage setting process are subject to some form of imperfections.

In an economy populated by an exogenous share of non ricardian consumers, wage stickiness affects both the response of aggregate variables to a government spending shock and the conditions for equilibrium determinacy.

Once wage stickiness is considered, the positive effect of government spending on aggregate consumption reported by the empirical studies of, *inter alia,* Blanchard and Perotti (2002), is not a robust feature of the model with rule of thumb consumers. In particular, it can be replicated just when the marginal disutility of labor effort is low. Contrary to Bilbiie (2003), we have shown that, for a wide set of parameter configurations, the Taylor Principle leads to equilibrium determinacy. Further, determinacy regions are similar to those obtained in a representative agent model under the majority of interest rate setting rules.

Our results suggest that the determinacy properties of the model with non ricardian consumers depends on the kind of nominal rigidities considered. For this reason, we warn against reappraisals of the conduct of monetary policy in

[14] The case of a central bank reacting to wage inflation can be found on the appendix to the paper provided on the web site mentioned in footnote 13.

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 (2005) in a sticky prices-flexible wages economy, could be obscured by considering a modest degree of wage stickiness. This is part of our ongoing research.

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Appendix.

Log-linearized equilibrium conditions.

This appendix provides a log-linear approximation to the equlibrium conditions of the model economy described in the text. For a detailed derivation see also

GVL.

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

$$c_t^o - E_t c_{t+1}^o = -E_t\left(r_t - \pi_{t+1}\right) \tag{21}$$

Log-linearization of equations (6) and (8) leads to the dynamic of (real)Tobin's Q

$$q_t = \left(1 - \beta\left(1 - \delta\right)\right) E_t r_{t+1}^k + \beta E_t q_{t+1} - \left(r_t - E_t \pi_{t+1}\right) \tag{22}$$

and its relationship with investment:

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

Equation (10) determines the following log-linear form for consumption of non ricardian agents

$$c_t^{rt} = \frac{(1-\alpha)}{\mu_p \gamma_c}\left(l_t + \omega_t\right) - \frac{1}{\gamma_c} t_t^r \tag{23}$$

while the assumption that consumption level are equal at the steady state implies that aggregate consumption is

$$c_t = \left(1 - \lambda\right) c_t^o + \lambda c_t^r \tag{24}$$

The stock of capital evolves according to

$$\delta i_t = k_t - \left(1 - \delta\right) k_{t-1} \tag{25}$$

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

$$y_t = \gamma_c c_t + g_t + \left(1 - \widetilde{\gamma}_c\right) i_t \tag{26}$$

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

$$y_t = \left(1 - \alpha\right) l_t + \alpha k_{t-1} \tag{27}$$

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

$$b_t = \left(1 + \rho\right)\left(b_{t-1} + g_t - t_t\right) \tag{28}$$

The New Keynesian Phillips is obtained through log-linearization of condition (2) and reads as

$$\pi_t = \kappa_p mc_t + \beta E_t \pi_{t+1} \tag{29}$$

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

Equations (21) through (29), equation (19) together with the policy rules (14) and (16)determine the equilibrium path of the economy we have outlined.

Figures

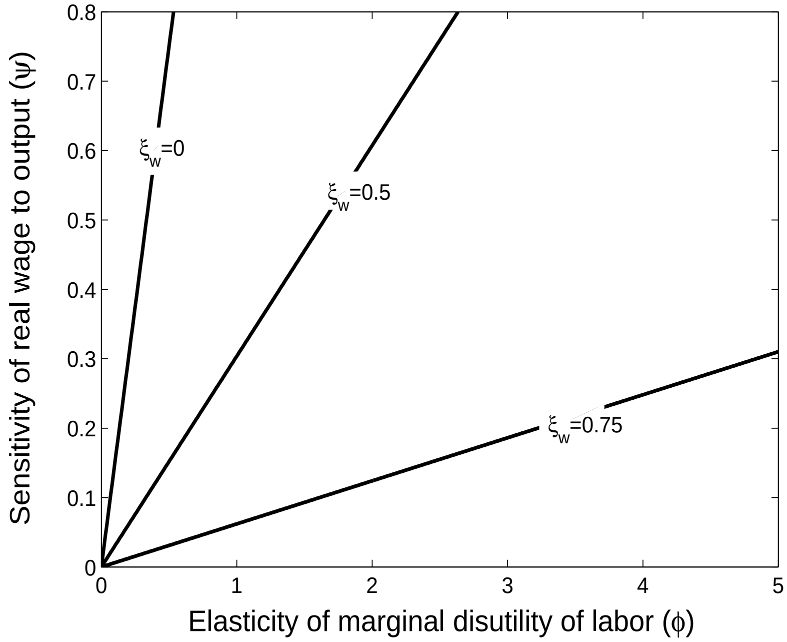

Figure 1: Sensitivity of real wage with respect to output as a function of the elasticity of marginal disutility of labor.

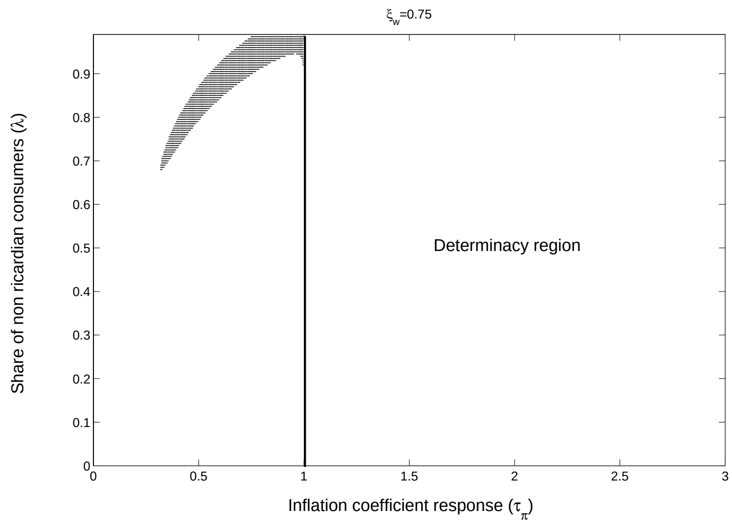

Figure 2: Determinacy region when wages have an average duration of 4 quarters ($\xi_w = 0.75$). Instability area in black.

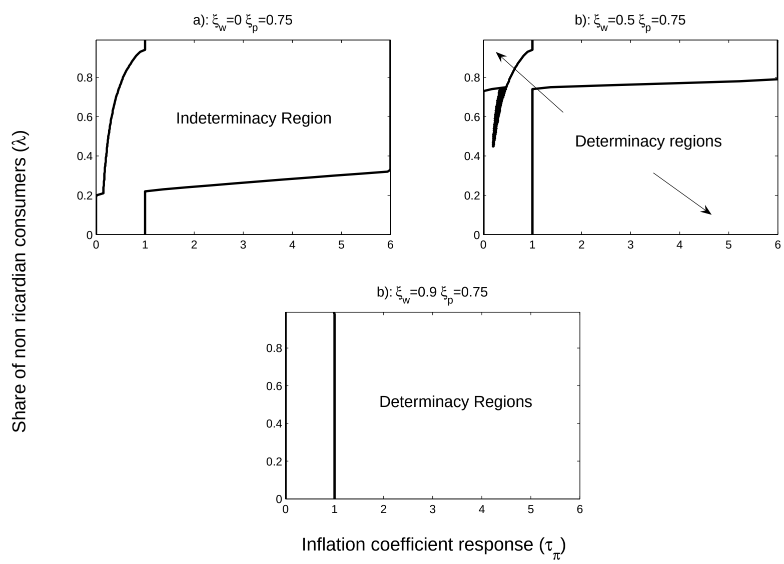

Figure 3: Indeterminacy regions under alternative degree of wage stickiness. Instability areas in black. Panel a ($\xi_w = 0$), panel b ($\xi_w = 0.5$) panel c ($\xi_w = 0.9$).

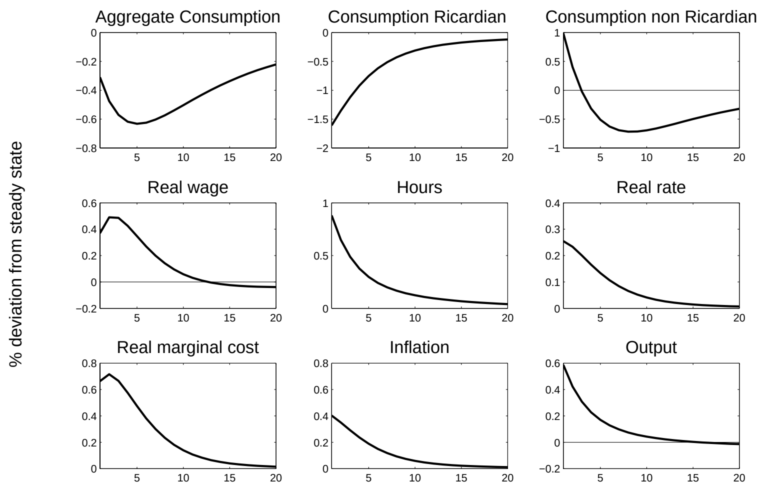

Figure 4: Impulse response functions to a government spending shock. Baseline parametrization.

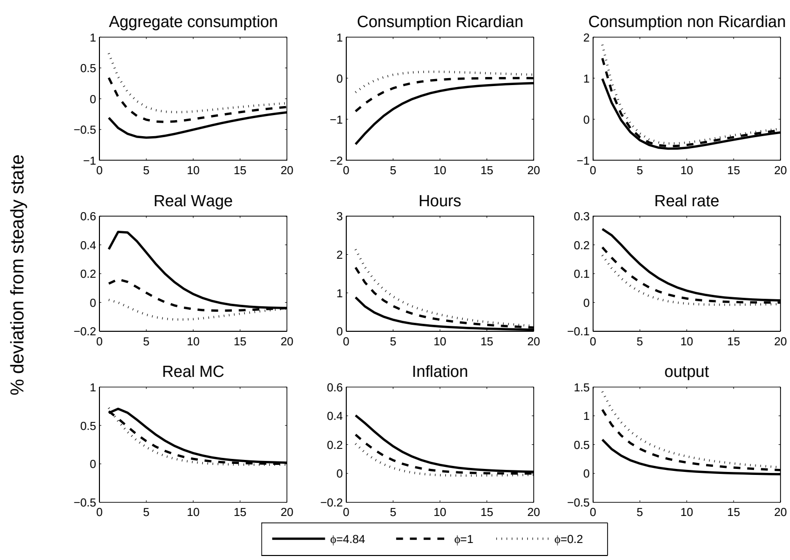

Figure 5: Impulse response functions to a government spending shock. Sensitivity to ϕ.

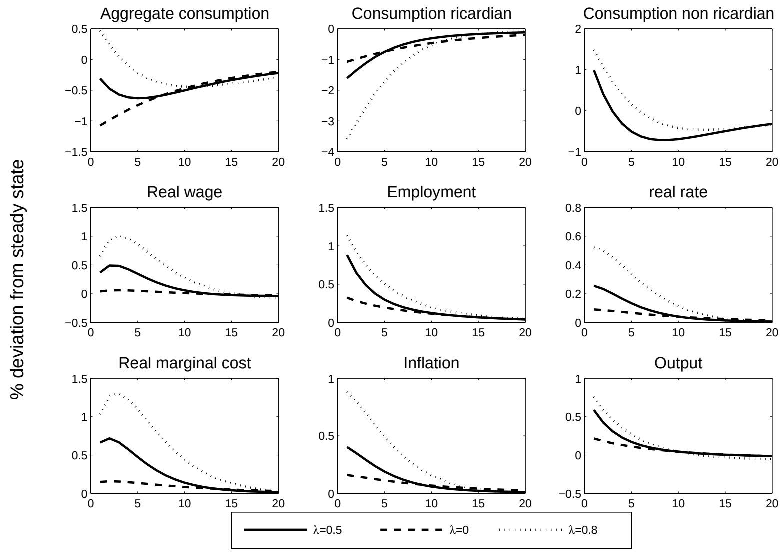

Figure 6: Impulse response functions to a government spending shock. Sensitivity to λ.

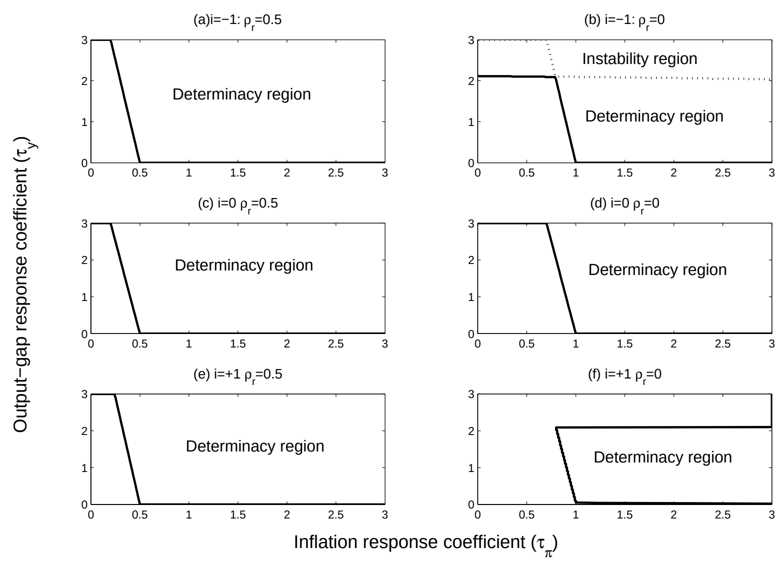

Figure 7: Indeterminacy regions under alternative monetary rules. $i = -1$: backward looking rule; $i = 0$ contemporaneous rule; $i = +1$ forward looking rule

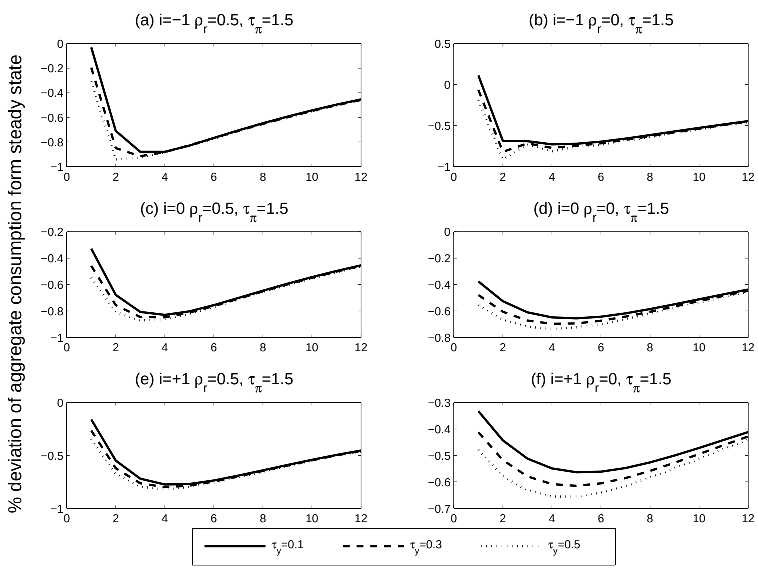

Figure 8: Response of aggregate consumption under alternative monetary rules. $i = -1$: backward looking rule; $i = 0$ contemporaneous rule; $i = +1$ forward looking rule