Fiscal Shocks and the Consumption Response when Wages are Sticky[1]

Francesco Furlanetto[2]

DEEP-HEC Lausanne and Norges Bank

October 2007

[1]This paper is part of my PhD thesis written at DEEP-HEC Lausanne. I thank, without implicating them, Philippe Bacchetta, Jean Boivin, Jean-Pierre Danthine, Jordi Gali, Jean Imbs, Tommaso Monacelli, Paolo Pesenti, Louis Phaneuf, Aude Pommeret, Martin Seneca, Luca Sessa, Tommy Sveen and Lutz Weinke for useful comments and discussions. I thank also seminar participants at DEEP, CREI, EEA 2006 in Vienna, ASSET 2006 in Lisbon, SAE 2006 in Oviedo, SCSE 2006 in Montreal, SSES 2007 in St. Gallen and job market seminars in Louvain la Neuve, Namur, HEC Montreal, Bank of Canada, CEU-MNB, Bern, Norges Bank, St. Andrews and UNSW Sydney. I acknowledge the financial support of HEC Lausanne and Swiss National Research Fund. The opinions expressed here are solely those of the author and do not necessarily reflect the views of Norges Bank.

[2]Norges Bank, PO Box 1179, Sentrum, 0107 Oslo, Norway. Email: francesco.furlanetto@norges-bank.no. Telephone: +47-22316128. Telefax: +47-22424062. Website: www.norges-bank.no/research/furlanetto/

Abstract

In this paper we study the impact of a government spending shock on aggregate consumption, building on the GLV (Gali, Lopez-Salido and Valles (2007)) model. We show that the GLV model implies a counterfactual increase in the real wage, the interest rate and the inflation rate. The introduction of sticky wages solves these problems and preserves the main result of the model, i.e. the positive response of consumption. Moreover, once we relax the common wage assumption, sticky wages are even essential to reproduce the positive response of consumption.

JEL Classification: E32, E62

Keywords: Sticky wages, rule-of-thumb consumers, fiscal shocks, firm-specific capital.

1 Introduction and motivation

The creation of a huge public deficit in the United States and the debate on the usefulness of strict budgetary rules in the European Union have renewed the interest in the effectiveness of government spending shocks as a stabilization tool. The emergence of empirical evidence based on Vector Autoregressions (VAR) (Perotti (2005) among many others)[1] should help researchers understand the impact of these shocks and discriminate between different economic models. The response of private consumption to a government spending shock has attracted the bulk of the interest in the literature because Keynesian and neoclassical models forecast opposite dynamics for this variable. Keynesian models, based on the IS-LM framework, predict a positive response of consumption, whereas neoclassical models, based on the RBC framework, imply a negative response (cf. Baxter and King (1993)). Somewhat surprisingly, the cited empirical evidence tends to favor the Keynesian model by finding a positive and significant response of consumption, at least in the United States and despite the paper of Perotti (2005), which points to a decline in the effectiveness of fiscal shocks in the last twenty years.

Some authors have tried to reconcile the analytical rigor of the RBC framework with the empirical evidence by adding additional features to that model. For instance, the New Keynesian literature introduces monopolistic

[1] A non-exhaustive list includes: Blanchard and Perotti (2002), Fatas and Mihov (2002), Gali, Lopez-Salido and Valles (2007), Burnside, Eichenbaum and Fisher (2004) and Mountford and Uhlig (2002).

competition and sticky prices into the RBC model. However, these ingredients, which are very useful to study monetary shocks, are not sufficient to obtain plausible dynamics in the case of fiscal shocks. In fact, a standard New Keynesian model with a public sector cannot reproduce a positive response of consumption because the transmission mechanism is based, as in the RBC literature, on a negative wealth effect (Linnemann and Shabert (2003)).

One way to obtain a positive response of consumption has been proposed by Gali, Lopez-Salido and Valles (GLV) (2007).[2] Following the suggestion in Mankiw (2000), GLV introduce "rule-of-thumb consumers" (ROT) into the basic New Keynesian model to explain the excessive dependence of aggregate consumption on current income compared to the predictions of the "permanent income theory". These consumers cannot optimize intertemporally because of borrowing constraints, lack of access to financial markets or simply because they are myopic. Each period, they consume their current disposable income and do not save; they coexist with optimizing agents (OPT), who take consumption decisions according to the "permanent income hypothesis". OPT agents are more sophisticated because they can hold bonds,

[2] In the literature, three other solutions have been proposed to account for the evidence on consumption. The first is to include government spending in the utility function as a complement of private consumption (see Bouakez and Rebei (2007) for an application in the RBC framework). The result depends crucially on the calibration of the coefficient of risk aversion. A second possible solution is to consider productive government spending, i.e. to introduce government spending in the production function (Linnemann and Shabert (2005)). However, the result depends on the production elasticity of government spending. Linnemann (2006) proposes a third way to obtain a positive response of consumption: a non additively separable utility function in consumption and labor, combined with a small intertemporal elasticity of substitution in consumption, guarantees a positive response of consumption in the baseline RBC model. For a criticism to this approch see Bilbiie (2006).

rent capital to firms and receive profits derived from firm ownership. ROT agents are a very simple device to break Ricardian equivalence: since they do not optimize intertemporally, it matters for them whether an increase in government spending is financed through an increase in taxation or through a budget deficit. In the first case their current income decreases, whereas in the second case it is not affected. Hence, this model enables us to study the impact of fiscal shocks that are not budget balanced, i.e. the kind of fiscal shocks that are more plausible in reality.

A government spending shock financed, at least in part, through a budget deficit, affects the two types of consumers in different ways. OPT consumers, on the one hand, reduce their consumption rationally in the anticipation that taxes will increase sooner or later. ROT consumers, on the other hand, can increase consumption if their current income increases. The response of aggregate consumption is positive as long as the positive response of ROT consumption is bigger than the negative response of OPT consumption. This is the case in a model with deficit financing, sticky prices and monopolistic competition in the labor market (GLV (2007)). In figure 1 we can see how the introduction of ROT agents changes crucially the responses of these key variables: the dashed line represents the traditional New Keynesian model (100% of OPT agents), the solid line is the same model (under the same calibration) but with 50% of OPT agents and 50% of ROT agents (GLV (2007)).

However, this result relies on a big increase in the real wage that pushes up the current income of ROT consumers. This is not a desirable property of the model because the large positive response of the real wage is counterfactual. The evidence on the response of real wages to government spending shocks favors a very limited response: in Fatas and Mihov (2001) the maximum response of the real wage is around 0.4% following a 1% increase in the government spending/output ratio but the estimate is never significant. In their VAR, GLV find the same quantitative result as Fatas and Mihov, and the estimate is significant only three quarters after the shock, whereas in the theoretical model the predicted increase in the real wage is around 2%. Furthermore, as argued by Bilbiie and Straub (2004), this large reaction of the real wage is not consistent with the "Lucas less famous critique", saying that real wages are roughly acyclical. Real wages are procyclical responding to productivity shocks. If they are also strongly procyclical with respect to government spending shocks, it seems difficult to reproduce the aggregate acyclicality observed in the data. Moreover, the GLV model predicts a big increase in the interest rate and in the inflation rate that are also counterfactual. The inflation response is not significant in almost all the studies cited above whereas the interest rate response is significant only in some studies (Perotti (2005) finds a positive and significant response of the interest rate only in the period 1980-2001). By construction, the introduction of wage stickiness in the model prevents the counterfactual swings in these three variables. However, wage rigidity could make it difficult to confirm the increase in consumption because it prevents the large increase in current income that pushes up ROT consumption. Thus, intuitively, we could imagine a tension between wage stickiness and the positive response of consumption. The goal of this paper is to check this conjecture in the GLV model augmented with sticky wages and in a more general model where we allow for heterogeneity in wages.

In the literature, we can find many arguments to justify the introduction of sticky wages into our model. Probably the most convincing is found in Christiano, Eichenbaum, Evans (2005): according to their results, sticky wages are essential to reproduce plausible dynamics in aggregate variables responding to a wide variety of economic shocks. They find strong evidence in favor of sticky wages and estimate a degree of nominal wage rigidity much higher than the degree of price rigidity. Sticky wages have been introduced in a New Keynesian model by Erceg, Henderson and Levin (2000). Since then, sticky wages have become a standard ingredient in this kind of model.

One could imagine that the successful result of GLV relies heavily on the counterfactual increase in the real wage and that it is not robust to the introduction of a more realistic modeling of the labor market. However, the main result of the paper is that this intuition is not correct and that a model with sticky wages preserves the crowding-in of consumption: the GLV result is strongly confirmed under more restrictive conditions. The mechanism is the following. As expected, nominal wage rigidity implies that wage inflation is much lower and thus the reaction of the real wage is also low (it is almost fixed). In fact ROT consumption increases less, following current income closely. However, a second effect is at work. Lower wage inflation implies a lower impact on marginal cost, less price inflation and a much lower increase in the interest rate by the monetary authority. This lower increase in the interest rate crucially affects OPT consumption and investment: both decrease less than in the flexible wage case. It turns out that for realistic calibrations the two effects have almost the same size and thus the positive response of consumption is preserved.

The positive response of consumption in a model with sticky wages is a very robust result. It holds under a higher elasticity of marginal labor disutility, a lower degree of price stickiness and it does not depend on the form of the wage rigidity. As an additional robustness check and for the sake of realism, we modify the capital accumulation process. Having firm-specific capital, instead of rental rate capital, enables us to lower the degree of price stickiness in the model because firm-specific capital lowers the marginal cost response to demand shocks, as shown by Sveen and Weinke (2005). In GLV (2007) the positive response of consumption relies on four quarters of price stickiness, which according to Bils and Klenow (2004) and Steinsson and Nakamura (2007) is a too high value. Introducing firm-specific capital in the model, we can obtain the positive response of consumption under only two quarters of price stickiness.

Finally, we relax the common wage assumption in the labor market. In GLV (2007) all agents earn the same wage and work the same number of hours, irrespective of their consumption behavior. A plausible alternative is a model where ROT and OPT agents are allowed to choose their own wage optimally and to work a different number of hours. Our second important result is that in a model with flexible wages the positive response of consumption is not preserved once we depart from the common wage assumption. However, the result is rescued when sticky wages are introduced. Under sticky wages the impact of wage heterogeneity in the model is strongly reduced and the dynamics are similar to the model with a common wage. Thus the main point of our paper is that not only sticky wages and the positive response of consumption can coexist, but even the former can be a necessary assumption to obtain the latter.

The rest of the paper is organized as follows. In section 2 we present the model, in section 3 we show the results of our numerical simulations and we check the strength of our results under different calibrations. In section 4 we modify the wage rigidity, introducing real wage rigidity as in Blanchard and Gali (2007), we change the capital accumulation process, using firm-specific capital instead of rented capital, and finally we improve the labor market structure, allowing for heterogeneity in wages. In section 5 we conclude.

2 The model

The economy is composed of a continuum of households and a continuum of firms producing intermediate goods that are transformed into a final good by a perfectly competitive firm. The central bank fixes the nominal interest rate following a simple "Taylor rule". The fiscal authority collects taxes, buys a fraction of the final good and issues one-period bonds. Wages are set by a continuum of unions, whereas hours worked are determined by labor demand. In the next subsections we analyze the behavior of each agent.

2.1 Households

The model is composed of a continuum of agents indexed on $[0, 1]$: a fraction $[0, \lambda]$, the "rule-of-thumb" agents, consume their disposable income each period and a fraction $(\lambda, 1]$, the "optimizing" agents, optimize intertemporally and behave according to the permanent income hypothesis. OPT agents can trade a full set of Arrow-Debrew securities in complete financial markets. The generic household is indexed by $i \in [0, 1]$.

2.1.1 Optimizing households

A typical optimizing household, indexed by the superscript o, derives utility from consumption (C_t^o) and disutility from hours worked (N_t^o), and maximizes the sum of expected future utilities discounted at the rate of time preference $\beta \in (0, 1)$:

$$E_0 \sum_{t=0}^{\infty} \beta^t U^o (C_t^o, N_t^o)$$

subject to the sequence of budget constraints

$$P_t\left(C_t^o + I_t^o\right) + R_t^{-1}B_{t+1}^o + P_tT_t^o + F_t = W_tN_t^o + +R_t^kK_t^o + B_t^o + D_t^o \qquad (1)$$

and the capital accumulation equation

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

where P_t is a price index, I_t^o is investment, R_t is the gross nominal interest rate, B_{t+1}^o is the quantity of one-period nominal bonds bought at the beginning of the period, T_t^o are lump-sum taxes and F_t is a membership fee to the union. The four sources of income are labor income $(W_tN_t^o)$, capital income $\left(R_t^kK_t^o\right)$, bond holdings paying one unit of the consumption index (B_t^o) and dividends derived from the ownership of monopolistically competitive firms (D_t^o). δ is the rate of depreciation, and $\phi\,(.)$ is an adjustment cost function satisfying $\phi\,(\delta) = \delta$, $\phi' > 0$, $\phi'\,(\delta) = 1$ and $\phi'' \leq 0$.

The utility function is given by

$$U^o\left(C_t^o, N_t^o\right) = \log C_t^o - \frac{N_t^{o1+\varphi}}{1+\varphi}$$

where φ is a parameter ≥ 0.

The household maximizes over consumption, investment and bond holdings. Its choice is summarized by the following first-order conditions that we write in log-linear form:[3]

$$c_t^o = E_t c_{t+1}^o - (r_t - E_t \pi_{t+1}) \tag{3}$$

$$k_{t+1} = (1-\delta) k_t + \delta i_t \tag{4}$$

$$q_t = -(r_t - E_t[\pi_{t+1}]) + [1 - \beta(1-\delta)] E_t \left[r_{t+1}^k - p_t\right] + \beta E_t [q_{t+1}] \tag{5}$$

$$i_t - k_t = \eta q_t \tag{6}$$

where $\eta \equiv -1/(\phi''(\delta)\delta)$. Here, (3) is the Euler equation, (4) is the capital accumulation equation, while (5) and (6) represent the dynamics of Tobin's q, denoted q_t, and its relation to investment, respectively.

The household does not maximize with respect to labor because we assume monopolistic competition in the labor market. The wage is fixed by unions and hours worked are determined by labor demand. We assume that the wage mark-up is sufficiently high to ensure that both types of households are willing to supply the quantity of labor demanded by firms.

2.1.2 Rule-of-thumb agents

ROT agents, indexed by the superscript r, have the same utility function as OPT consumers, $U^r(C_t^r, N_t^r) = \log C_t^r - \frac{N_t^{r1+\varphi}}{1+\varphi}$ but they do not choose consumption intertemporally. They simply consume their disposable income each period

[3] The reader can find a detailed derivation in GLV (2007). Lowercase variables denote log-deviations from the steady state of the corresponding uppercase variables.

$$P_t C_t^r = W_t N_t^r - P_t T_t^r - F_t \qquad (7)$$

ROT agents differ from OPT agents because they cannot smooth consumption through bond holdings and because they do not receive dividends. A first-order log-linear approximation around the steady state with constant consumption equalized across households gives

$$c_t^r = \Phi\left(rw_t + n_t^r\right) - \frac{1}{\gamma_c} t_t^r \qquad (8)$$

where $rw_t = w_t - p_t$, $\Phi = \frac{WN}{PC} = \frac{1}{\gamma_C \mu_p}(1-\alpha)$, μ_p represents the mark-up and $\gamma_c = \frac{C}{Y}$. Omission of time subscripts indicates steady-state variables. Note that the union membership fee drops out because the fee is assumed to be a quadratic function of wage inflation, which is zero in the steady state, cf. below.

2.1.3 Aggregation

Aggregate consumption is the average of both kinds of consumption weighted by the percentage of rule-of-thumb consumers (λ) in the economy

$$c_t = \lambda c_t^r + (1-\lambda) c_t^o \qquad (9)$$

Similarly, for aggregate hours

$$n_t = \lambda n_t^r + (1-\lambda)\, n_t^o$$

2.2 Firms

2.2.1 Final good producer

The final good Y_t is produced by a perfectly competitive firm that combines intermediate inputs $Y_t^d(j)$ into a final output through a constant returns to scale technology. The production function is given by

$$Y_t = \left(\int_0^1 Y_t^d(j)^{\frac{\epsilon_p - 1}{\epsilon_p}}\, dj \right)^{\frac{\epsilon_p}{\epsilon_p - 1}}$$

where ε_p represents the elasticity of substitution among intermediate goods indexed by $j \in [0,1]$.

Profit maximization and the assumption of perfect competition imply the following set of demand schedules for the intermediate goods

$$Y_t^d(j) = \left(\frac{P_t(j)}{P_t} \right)^{-\epsilon_p} Y_t$$

where $P_t(j)$ represents the price of the good produced by firm j. The zero-profit condition yields $P_t = \left(\int_0^1 P_t(j)^{1-\epsilon_p}\, dj \right)^{\frac{1}{1-\epsilon_p}}$.

2.2.2 Intermediate goods producers

A typical monopolistically competitive firm operates through the following technology

$$Y_t(j) = K_t(j)^{\alpha} N_t(j)^{1-\alpha}$$

where $K_t(j)$ is the capital stock owned by firm j and $N_t(j)$ is an aggregator of the different labor varieties indexed by z

$$N_t(j) = \left[\int_0^1 N_t(j,z)^{\frac{\varepsilon_w - 1}{\varepsilon_w}} dz\right]^{\frac{\varepsilon_w}{\varepsilon_w - 1}}$$

$N_t(j,z)$ represents the quantity of variety z labor employed by firm j. We assume that a fraction λ of type z workers is composed of ROT consumers and the rest of OPT consumers. The firm allocates labor demand proportionally.

Cost minimization yields a set of demand schedules for labor varieties z that after aggregation looks like

$$N_t(z) = \left(\frac{W_t(z)}{W_t}\right)^{-\varepsilon_w} N_t \tag{10}$$

where the wage index W_t is given by $\left(\int_0^1 W_t(z)^{1-\epsilon_w} dz\right)^{\frac{1}{1-\epsilon_w}}$ and ε_w represents the elasticity of substitution across labor types.

Each firm maximizes the sum of expected future discounted profits

$$\max \sum_{k=0}^{\infty} E_t \left\{ Q_{t,t+k} \left[P_{t+k}(j)\, Y_{t+k}^{d}(j) - W_{t+k} N_{t+k}(j) - R_{t+k}^{k} K_{t+k}(j) \right] \right\}$$

where $Q_{t,t+k}$ is the stochastic discount factor of optimizing consumers who own firms. It sets contingency plans for $P_{t+k}^{*}(j)$ subject to a set of constraints

$$P_{t+k+1}(j) = \begin{Bmatrix} P_{t+k+1}^{*}(j) \text{ with probability } (1-\theta_p) \\ P_{t+k}(j) \text{ with probability } \theta_p \end{Bmatrix}$$

$$Y_{t+k}^{d}(j) = \left(\frac{P_{t+k}(j)}{P_{t+k}} \right)^{-\epsilon_p} Y_{t+k} \tag{11}$$

Prices are set according to a Calvo mechanism.[4] A time t price setter chooses the price for its good $P_t(j)$ equal to $P_t^{*}(j)$, $P_t^{*}(j)$ being the price that maximizes the discounted value of dividends over the expected duration of the selected price. The firm takes into account that this price will stay in place the next period with probability θ_p, and that it will be allowed to reoptimize with probability $(1-\theta_p)$. Firm j is monopolistically competitive in the market for its good and thus is also constrained by the demand curve for good j (11).

As is well known, the optimality conditions from this problem imply the New Keynesian Phillips curve (NKPC)

$$\pi_t^{p} = \beta E_t \left(\pi_{t+1}^{p} \right) + \kappa_p mc_t \tag{12}$$

[4] For a detailed explanation of the Calvo (1983) mechanism see Woodford (2003).

where $\kappa_p = (1 - \beta\theta_p)(1 - \theta_p)\theta_p^{-1}$, $\pi_t^p = p_t - p_{t-1}$ is price inflation, and where mc_t is real marginal costs given by

$$mc_t = rw_t - (y_t - n_t) \tag{13}$$

In addition, cost minimization implies that relative factor inputs satisfy the condition

$$k_t + n_t = \left(r_t^k - p_t\right) + rw_t \tag{14}$$

To a first-order approximation, production is given by

$$y_t = \alpha k_t + (1 - \alpha) n_t \tag{15}$$

2.3 Unions

The economy has a continuum of unions, each representing a continuum of workers, a fraction $(1 - \lambda)$ are OPT agents, and a fraction λ are ROT agents. Each union sets the wage rate for its members, who stand ready to satisfy firms' demand for their labor services at the chosen wage. The workers in a union provide the same type of labor (irrespective of their consumption behavior) differentiated from the type of labor services provided by members of other unions. Firms do not discriminate between consumer types in its labor demand, and so it follows from the unions' problems that $n_t^r = n_t^o = n_t$. These assumptions imply that all the workers earn the same wage and work the same number of hours.

Each period, unions choose $W_t(z)$ to maximize the present value of an average of its member's current and future period utility functions, that is,

$$\max_{W_t(z)} E_t \sum_{k=0}^{\infty} \beta^{t+k} \left[\lambda U_{t+k}^r + (1-\lambda) U_{t+k}^o \right] \tag{16}$$

subject to the labor demand functions (10) and the budget constraints of its members (1) and (7), thus taking the effect of the wage decision on the income of its members into account. Wage adjustments are assumed to be costly. In particular, it is assumed that the wage adjustment cost is a quadratic function of the increase in the wage demanded by the union as modelled in Rotemberg (1982) for prices. For simplicity, the adjustment cost is proportional to the aggregate wage bill in the economy (this parallels the specification of price adjustment costs in Ireland, 2003). Though the wage bargaining process is not explicitly modelled, one way of thinking of this cost is that unions have to negotiate wages each period and that this activity demands economic resources; the larger the increase in wages obtained, the more effort unions would have needed to put into the negotiation process. Each member of the union covers an equal share of the wage adjustment cost by paying a union membership fee. Hence the nominal fee paid by a member of union z at time t is given by

$$F_t(z) = \frac{\phi_w}{2} \left(\frac{W_t(z)}{W_{t-1}(z)} - 1 \right)^2 W_t N_t$$

where the size of the adjustment costs is governed by the parameter ϕ_w. In the special case where $\phi_w = 0$, the model effectively collapses to the model in GLV (2007).

The first-order condition with respect to $W_t(z)$ is given by

$$\begin{aligned} 0 &= \left(\frac{\lambda}{C_t^r} + \frac{(1-\lambda)}{C_t^o}\right)\frac{W_t}{P_t}\left[(\varepsilon_w - 1) + \phi_w\left(\Pi_t^w - 1\right)\Pi_t^w\right] - \varepsilon_w N_t^{\varphi} \\ &\quad -\beta E_t\left[\left(\frac{\lambda}{C_{t+1}^r} + \frac{(1-\lambda)}{C_{t+1}^o}\right)\phi_w\left(\Pi_{t+1}^w - 1\right)\Pi_{t+1}^w\frac{W_{t+1}}{P_{t+1}}\frac{N_{t+1}}{N_t}\right] \end{aligned}$$

whose log-linearized version is a NKPC for wage inflation (Π^w)

$$\pi_t^w = \beta E_t\left(\pi_{t+1}^w\right) + \kappa_w\left(mrs_t - (w_t - p_t)\right) \tag{17}$$

where mrs_t is the average marginal rate of substitution given by

$$mrs_t = c_t + \varphi n_t \tag{18}$$

and the slope coefficient κ_w is[5]

$$\kappa_w = \frac{\varepsilon_w - 1}{\phi_w}$$

[5] Instead of wage adjustment costs, we may assume that a union is allowed to reset its wage rate each period with a fixed probability $1-\theta_w$ as in Calvo (1983). But to undo the implications of the implied heterogeneity across unions, a risk-sharing arrangement between unions must be in place. This follows since rule-of-thumb consumers are barred from sharing risk through financial markets. Results, however, are very similar. In particular we would get a Phillips curve with $\kappa_w = (1-\beta\theta_w)(1-\theta_w)\theta_w^{-1}(1+\varphi\varepsilon_w)^{-1}$. Alternatively, each household must be assumed to provide all types of labor simultaneously in (as in Schmitt-Grohe and Uribe (2006)). However, this formulation is, in our opinion, in contrast to the assumption of monopolistic competition in the labor market since labor variety z would be supplied by all agents.

Unions are essential in the model to avoid different wages among type z agents. If a household was free to choose its wage, it would choose it as a mark-up over its marginal rate of substitution. And since consumption levels are different between ROT and OPT agents, marginal rates of substitution and wages would also be different. In section 4 we relax the common wage assumption, introducing two different wages for ROT and OPT agents.

2.4 Monetary and fiscal policy

Monetary policy is set by the central bank according to a simple interest rate rule that is a special case of the well-known "Taylor rule"

$$r_t = r + \phi_\pi \pi_t \tag{19}$$

where $r_t = R_t - 1$, r is the steady state value of the nominal interest rate and ϕ_π measures the reaction of monetary policy to current inflation.

The government has to satisfy the following budget constraint

$$b_{t+1} = (1+\rho)(b_t + g_t - t_t) \tag{20}$$

where $\rho = \frac{1}{\beta} - 1$.

Taxes are set according to the fiscal rule

$$t_t = \phi_b b_t + \phi_g g_t \tag{21}$$

where $g_t = \frac{G_t - G}{Y}$, $t_t = \frac{T_t - T}{Y}$ and $\frac{\left(\frac{B_t}{P_{t-1}}\right) - \left(\frac{B}{P}\right)}{Y}$. ϕ_b and ϕ_g are positive constants reflecting the weights assigned by the fiscal authority to debt and current government spending. The condition $\phi_b > \frac{\rho}{1+\rho}$, rules out explosive debt dynamics.

Government spending (normalized by steady state output and expressed in deviations from steady state) evolves exogenously according to the following first-order autoregressive process

$$g_t = \rho_g g_{t-1} + \epsilon_t \tag{22}$$

where $0 < \rho_g < 1$ measures the persistence of the shocks and ϵ_t measures the size of the shock.

2.5 Market clearing and steady state

The clearing of labor and goods markets requires for all t

$$N_t(z) = \int_0^1 N_t(z, j)\, dj \text{ for all } z$$

$$Y_t(j) = Y_t^d(j) \text{ for all } j$$

$$Y_t = C_t + I_t + G_t + F_t$$

whose log-linearized version is

$$y_t = \gamma_c c_t + \gamma_I i_t + g_t \tag{23}$$

where $\gamma_I = \frac{I}{Y} = \frac{\alpha\delta}{(\rho+\delta)\mu_p}$. As GLV (2007), we look at a steady state with zero inflation, zero public debt and a balanced primary deficit. To simplify the solution of the model, it is convenient to impose $C^o = C^r$. Since we are interested in the dynamic responses to shocks, and not in the characterization of the steady state, we see this assumption as a useful simplification. However, in steady state ROT and OPT agents differ because the latter earn dividends and capital income. Therefore, to achieve the same steady state consumption, OPT agents must be taxed more than ROT agents. For simplicity, and to facilitate comparability of results, we do not depart from GLV and we set different tax levels in steady state. Moreover, Natvik (2007) shows that, provided that wages are sticky, equilibrium dynamics are not affected by the assumption on steady state consumption. Equations (3) to (6) , (8), (9), (12) to (15) and (17) to (23) form a system of stochastic difference equations that can be solved using standard techniques.

3 Results

As a baseline calibration we choose the same parameter values as GLV (2007). We made this choice to facilitate the comparability of the results. As GLV (2007), we set $\delta = 0.025$, $\alpha = 0.33$, $\eta = 1$, $\beta = 0.99$, $\lambda = 0.5$, $\gamma_g = 0.2$, $\phi_\pi = 1.5$, $\phi_b = 0.33$, $\phi_g = 0.1$, $\varepsilon_p = 6$, $\theta_p = 0.75$, $\rho_g = 0.9$ and $\varphi = 0.2$.

We need to fix a value for ϕ^w (the adjustment costs parameter) and ε_w (the elasticity of substitution between labor varieties) that are not present in GLV where wages are flexible. We set ε_w equal to 4 (the implied wage mark-up in the case of flexible wages is $\frac{\varepsilon_w}{\varepsilon_w - 1}$) and $\phi^w = \frac{\varepsilon_w - 1}{(1-\beta\theta_w)(1-\theta_w)\theta_w^{-1}(1+\varphi\varepsilon_w)^{-1}} = 62.9$. This choice yields the same NKPC for wages as in a Calvo setting à la Erceg, Henderson and Levin (2000) with four quarters of wage stickiness ($\theta_w = 0.75$).

3.1 The effect of sticky wages

In figure 2 we can see the effects of sticky wages on some crucial variables. The dashed line represents the GLV model with flexible wages, the solid line represents the extension with sticky wages. The size of the shock is a one percent increase in the government spending to output ratio. In figure 2 we can observe the first important result of this paper: even though under sticky wages the response of the real wage is flat, the consumption response is still positive.

It is true that, as expected, lower wage inflation (implied by the wage stickiness) lowers the increase in ROT consumption since current labor income increases less than in the flexible wage case. However, a second effect goes in the opposite direction. In fact, lower wage inflation implies a lower increase in the marginal cost that in turn implies a lower increase in price inflation. But lower inflation translates into a lower increase in the interest rate by the central bank, and a lower increase in the interest rate has an expansionary effect on OPT consumption and investment. Hence, the response of aggregate consumption depends on the strengths of the two effects. In our model, the latter (the interest rate effect) almost offsets the former (the real wage effect), and aggregate consumption can still rise after a government spending shock. Thus, our initial speculation was not correct: the crowding-in of consumption does not rely on the counterfactual increase in the real wage, but it is a more robust result that is preserved under a more realistic specification of the labor market.

As a corollary, we see that in the model with sticky wages the reaction of ROT and OPT consumption is less asymmetric. It is still true that ROT consumers increase their consumption while OPT consumers decrease it, but the quantitative difference is now much lower.

The effect on all the other variables is summarized in figure 3. The first three panels show that we are dealing with a government spending shock that does not maintain a balanced budget. This is crucial in a model with ROT agents: with OPT agents alone, Ricardian equivalence would hold and therefore the presence of a budget deficit would be irrelevant. With ROT agents, the occurrence of a budget deficit crucially changes the spending multipliers. The introduction of sticky wages affects by construction the inflation rate and the interest rate response: the lower impact of the shock on the marginal cost implies a lower increase in inflation through the NKPC, and in the interest rate through the Taylor rule. The lower increase in the interest rate favors consumption and investment (whose reaction is now slightly positive) and the increase in aggregate demand pushes up output.[6] Labor demand increases, and hours follow this pattern since agents are willing to supply the quantity of labor demanded by firms.

To sum up, the introduction of sticky wages eliminates the large counterfactual positive response of the real wage, the inflation rate and the interest rate whereas it affects only marginally investment and consumption. Hours and output behave in the same way, independently of the degree of wage stickiness. Thus, sticky wages can correct the weaknesses we identified in the GLV model while preserving the positive response of consumption.

3.2 Sensitivity analysis

In figure 4 we conduct a sensitivity analysis on the impulse response function for consumption with respect to some key parameters in the model with sticky wages.

The parameter φ deserves special attention: in the traditional business cycle literature it represents the elasticity of the marginal labor disutility and it is inversely related to the Frish elasticity of labor supply. Following Rotemberg and Woodford (1997), GLV (2007) fix it at 0.2 to be consistent

[6] We note that the crowding-out effect of government spending on investment, described in all textbooks on intermediate macroeconomics (Mankiw (2000) among others), is not confirmed under our baseline calibration: this result is consistent with the result of Perotti (2005) who found a positive response of investment, at least for the period 1960-80 in a sample of OECD countries. In general, in this kind of model the response of investment is negative (GLV (2007) among others). In our paper we can obtain a positive response because of the low interest rate response. However, the positive response is not a robust result as it is for consumption: it depends on the adopted calibration.

with an elasticity of the real wage with respect to output (for a given level of consumption and employment) of 0.3. This value, however, is very low when we interpret φ in terms of the labor supply elasticity: in the literature the standard calibration goes from 1 to 3 (as in Gali and Monacelli (2005)). GLV use a much lower value because for higher values of φ the model exhibits indeterminacy. However, as shown by Colciago (2007), under sticky wages the determinacy region is larger and thus we can lower the labour supply elasticity towards more realistic values. In figure 4.1, we see that the positive response of consumption in our model is strongly confirmed, even when the labor supply becomes quite inelastic ($\varphi = 3$).

In contrast to GLV (2007), the positive response of consumption is preserved under only two quarters of price stickiness, consistent with empirical evidence provided by Bils and Klenow (2005) (see figure 4.2). This is the case because wage stickiness can partially substitute for price stickiness by lowering the marginal cost reaction.

The third parameter we consider is the percentage of rule-of-thumb consumers (λ): we see that 25% is the threshold that reproduces a zero response in consumption (figure 4.3).

Following the RBC literature (King and Watson (1996)), GLV choose the value of 1 for η, the elasticity of the investment to capital ratio with respect to Tobin's Q. A higher value of η reduces the size of adjustment costs in investment and allows this variable to fluctuate more. In figure 4.4 we see that even when this value is raised to 11 the response of consumption is almost unaffected.

In figure 4.5 we consider the parameter ϕ_g in the fiscal rule: when it is fixed at zero the increase in government spending is entirely deficit-financed, whereas when it is fixed at one the shock is budget-balanced. In the baseline calibration the shock is almost entirely deficit-financed $\left(\phi_g = 0.1\right)$. When the shock is budget-balanced $\left(\phi_g = 1\right)$, the response of consumption becomes significantly negative. We insist on the fact that this model enables us to study deficit-financed shocks that have very different implications with respect to budget-balanced shocks: in a model with only Ricardian consumers this difference vanishes.

4 Alternative specifications

In this section we first change the form of the wage rigidity. Instead of sticky nominal wages, we introduce real wage rigidity as in Blanchard and Gali (2007). Then, we model the capital accumulation process as firm-specific, as in Sveen and Weinke (2005). Finally, we relax the common wage assumption and we allow for heterogeneity in wages.

4.1 Different wage rigidities

In our baseline case we model the nominal wage rigidity using quadratic adjustment costs à la Rotemberg. In figure 4.6 we show that the positive response of consumption is independent of the form and the degree of wage rigidity. To see this point we consider the rather extreme case of a fixed nominal wage (dashed line): even in this case the positive response of consumption is preserved. An alternative way to model wage rigidity can be found in Blanchard and Gali (2007). They propose the following (admittedly ad-hoc) wage schedule modeled as a partial adjustment mechanism:

$$rw_t = \gamma rw_{t-1} + (1-\gamma)(c_t + \varphi n_t)$$

In this framework real wages react only in part to changes in the marginal rate of substitution and the parameter γ is considered as an index of real wage rigidity. In figure 4.6 we consider the case of partial real wage rigidity ($\gamma = 0.75$, dotted line). The response of consumption is still positive and hence our result is independent of the postulated wage rigidity (either nominal or real).[7]

4.2 Firm-specific capital

The "rental rate assumption" used in GLV (2007) is not a satisfactory way of modelling the capital accumulation process: it is more realistic to assume that the investment decision is made at the firm level. As shown by Danthine and Donaldson (2002), the rental rate assumption is innocuous in the RBC

[7] Although in this model nominal wage rigidity and real wage rigidity share the same properties, it is not always the case. Blanchard and Gali (2007) study the optimal monetary policy problem: under real wage rigidity it is not possible to stabilize the output gap and inflation at the same time, whereas it is the case under nominal wage rigidity (if inflation is considered as a weighted average of price inflation and wage inflation).

framework because the "rental rate" model and the "firm-specific" model are isomorphic. However, with sticky prices the two models are isomorphic only if the market for capital goods reopens after any shock, and firms with high demand (the ones whose price is fixed) can acquire the additional capital they need from firms who face low demand (the ones that changed their price recently). Danthine and Donaldson (2002) argue that ”it is feasible for price constrained firms, at the last minute, to unbolt machines and ship them to the market while it is too costly for them to print new price lists!”. On the basis of this argument, the recent literature that introduces firm-specific capital in the New Keynesian framework seems very promising. Under the firm-specific assumption, capital becomes productive only after one period, and the marginal cost becomes firm-specific, depending on the history of price adjustments. Firms with high demand cannot rent more capital in the market and thus must increase the labor input. In that way firms with high demand face a higher marginal cost and a lower capital/labor ratio. It turns out that the marginal cost depends not only on economy-wide factors (as in the rental rate case) but also on the output of the firm. A government spending shock raises the economy-wide component of the marginal cost, and thus a firm that is allowed to reoptimize its price will plan to raise it. However, the rise in price would reduce output, which in turn would lower the marginal cost, and this second effect happens only if capital is firm-specific. Therefore, the firm will increase its price by less than what it would have done if capital were not predetermined.

In a series of very influential papers, Sveen and Weinke (2005 and 2007) show that from a technical point of view the introduction of firm-specific capital in the New Keynesian model affects only the NKPC. (12) now looks like:

$$\pi_t = \beta E_t \pi_{t+1} + \kappa_p^{firm\ specific} mc_t$$

where $\kappa_p^{firm\ specific} < \kappa_p^{rental\ rate} = \frac{(1-\beta\theta_p)(1-\theta_p)}{\theta_p}$. Thus the NKPC looks flatter. The coefficient $\kappa_p^{firm\ specific}$ is a complicated function of structural parameters and has to be computed numerically: $\kappa_p^{firm\ specific}(\beta, \theta, \varepsilon_p, \eta, \alpha, \delta)$. We use the procedure proposed by Woodford (2005) and implemented by Christiano (2005).

In figure 5 we can evaluate the impact of firm-specific capital on the consumption response: the solid line represents the model with sticky wages and firm-specific capital and the dashed line is the baseline calibration of GLV with flexible wages and rental capital. We see that firm-specific capital reinforces the mechanism described in section 3 for sticky wages: both sticky wages and firm-specific capital reduce the marginal cost reaction to a government spending shock, and this real rigidity translates into lower inflation and a lower reaction by the monetary policy authority. The lower increase in the interest rate pushes OPT consumption and investment further up, inducing the same increase in consumption as in GLV (2007). The main message from figure 5 is that the GLV result on consumption is reinforced under a more realistic modeling of the capital accumulation process. Notice that under our baseline calibration $\kappa_p^{firm\ specific}$ is 0.0216. This value is rather low but not far from the estimated values in Gali, Gertler and Lopez-Salido (2001) and Eichanbaum and Fisher (2005) ranging between 0.03 and 0.05. $\kappa_p^{rental\ rate}$ would be 0.085.

Sveen and Weinke (2005) exploit the expansionary properties of firm-specific capital to lower the degree of price stickiness in the model. We can do the same for government spending shocks. In figure 5.2 we see that under two quarters of price stickiness the GLV model exhibits a negative response of consumption whereas in the model with firm-specific capital and sticky wages the consumption response is still largely positive. Under two quarters of price stickiness $\kappa_p^{firm\ specific}$ is 0.12 whereas $\kappa_p^{rental\ rate}$ would be 0.5. Firm-specific capital can thus reconcile the positive response of consumption, the empirical evidence on price rigidity (Bils and Klenow (2005) and Nakamura and Steinsson (2007)) and, to some extent, the empirical evidence on the slope of the NKPC (Gali, Gertler and Lopez-Salido (2001).

Woodford (2005) argues that, once firm-specific capital is introduced, it is more appropriate to infer a value for the elasticity of the investment to capital ratio with respect to Tobin's Q from firm-specific data. Gilchrist and Himmelberg (1995) estimate this elasticity using firm level data from the manufacturing sector over the period 1985-1989: they find a value equal to 12.1, very close to the value suggested by Woodford (2005), that is, 13.3. However, this value is very high compared with the estimates based on aggregate data (Christiano and Fisher (1998)). In figure 5.3 we see that, even using a value of 12.1, the response of consumption is almost unaffected. In figure 5.4 we see that the positive response of consumption is preserved even when labor supply is extremely inelastic.

4.3 Heterogeneity in wages

In the baseline version of our model we keep the assumption of a common wage between ROT and OPT agents to facilitate the comparison with GLV (2007). A legitimate question is to test whether the results are affected by the common wage assumption. In this section we allow both kinds of agents to choose their own wage, while being ready to supply the quantity of labor demanded by firms. The form of the wage rigidity (à la Rotemberg) implies that all ROT agents choose the same wage. Nevertheless, this wage is different from the one chosen by OPT agents, who have a different marginal rate of substitution. A similar modeling choice can be found in Bilbiee and Straub (2004), where wages are flexible instead of sticky and there is perfect competition in the labor market. The GEM model developed at the IMF incorporates ROT consumers and a similar specification of the labor market (Faruquee et al. (2006)). This modeling choice implies a forward-looking wage equation for OPT agents and a static wage equation for ROT agents:

$$\pi_t^{wo} = \beta E_t \pi_{t+1}^{wo} - \kappa_{wo} \left(rw_t^o - c_t^o - \varphi n_t^o \right)$$

$$\pi_t^{wr} = -\kappa_{wr} \left(rw_t^r - c_t^r - \varphi n_t^r \right)$$

A detailed derivation of these two equations can be found in the appendix.

In figure 6 we plot the responses to a government spending shock under the baseline calibration. The dashed line indicates the model with flexible wages and rental rate capital. We now identify a different response in OPT wages and in ROT wages. OPT wages decline slightly because of the wealth effect that lowers the marginal rate of substitution of OPT agents (MRS^o). MRS^r does not decline since the wealth effect does not hit ROT agents. The ROT wage increases, whereas the OPT wage declines, essentially because of the wealth effect and the different marginal rates of substitutions. At the same time firms have the incentive to hire more OPT labor since the costs are lower. OPT hours increase considerably and ROT hours increase only slightly. Moreover, the delayed response of taxes explains the hump-shaped response of ROT hours. Current income of ROT agents increases only slightly and the response of ROT consumption is low. The effect on aggregate consumption is almost negative.

This result is very important because it shows that the positive response of consumption is lost once we depart from the common wage assumption. However, the positive response of consumption is rescued when sticky wages are introduced (the dashed line): under four quarters of wage stickiness, the two wages react in similar ways and the same for hours worked. Under sticky wages the impact of wage heterogeneity in the model is strongly reduced and the dynamics are similar to the model with a common wage. Thus, our initial speculation on the impact of sticky wages is completely reversed. In section 3 we showed that sticky wages can coexist with a positive response of consumption under the common wage assumption. Here, we have just shown that sticky wages are even essential to obtain the positive response of consumption when wages are different. The most important result of this paper is thus that sticky wages confirm and generalize the validity of the GLV result. Two other recent papers find that sticky wages are useful in this framework. Colciago (2007) shows that the determinacy region is larger in a model with sticky wages. Natvik (2007), instead, investigate the impact of the assumption that all agents share the same consumption in steady state. He finds that, provided that wages are sticky, this assumption is innocuous. We believe that our results are complemented nicely by these related papers.

5 Conclusion

In this paper we study the responses of macroeconomic variables to a government spending shock in a model where Ricardian equivalence does not hold. We build on GLV (2007) and we show that it is possible to obtain a positive response of consumption, as observed in US data, avoiding a counterfactual increase in the real wage, the inflation rate and the interest rate. The key ingredient to eliminate the counterfactual dynamics in GLV (2007) is the introduction of sticky wages into the model. Even though the wage rigidity limits the increase in current income of ROT consumers, aggregate consumption can still rise because a lower increase in the interest rate favors OPT consumption and investment.

The sticky wage assumption, even if intuitively it was not the case, allows us to generalize the GLV result on several dimensions. In contrast to GLV (2007), our model can reproduce the positive consumption response under a low labor supply elasticity, a low degree of price stickiness, different form of wage rigidity and a more realistic capital accumulation process.

Moreover, once we relax the common wage assumption, sticky wages are even essential to reproduce the positive response of consumption. Since a substantial evidence supports the sticky wage assumption, we can conclude that the GLV result is strongly confirmed by our analysis and ROT consumers are an important ingredient to explain the impact of fiscal shocks.

This conclusion is reinforced in two companion papers. In Furlanetto and Seneca (2007b) we show that real rigidities can dramatically reduce the percentage of ROT consumers in the model. We can obtain the same consumption multiplier as in GLV (2007) having only 25% of constrained agents, instead of 50%, and two quarters of price stickiness, instead of four. In Furlanetto and Seneca (2007a) we show that ROT consumers are extremely useful also in explaining productivity shocks. Together with nominal and real rigidities, they make it easier to obtain the negative response of hours after a productivity shock as in Gali (1999). A large literature has shown the importance of nominal and real rigidity to explain business cycle dynamics. We show that financial frictions can also be useful.

This work can be extended in several directions. In the model, monetary policy is represented by a simple Taylor rule. An interesting question is to study how the presence of rule-of-thumb consumers influences the optimal monetary policy. A second extension concerns the open economy. Preliminary results from an open economy version of this model tell us that the model is able to reproduce a consumption multiplier that is declining in the degree of openness. This is a feature that is present in the data and that models with only optimizing consumers cannot deliver. A third project is to introduce complementarities in the utility function and productive government spending. A model with several features inducing a positive response of consumption could be meaningfully estimated using Bayesian methods to understand which feature is more relevant to explain the response of consumption.

References

[1] Baxter, M., King, R., 1993. Fiscal policy in general equilibrium. American Economic Review 83, 315-334.

[2] Bilbiie, F., 2006. Non-separable preferences, fiscal policy "puzzles" and inferior goods. Manuscript University of Oxford, available at

http://www.nuff.ox.ac.uk/Users/Bilbiie/index_files/RecentResearch.htm

[3] Bilbiee, F., Straub, R., 2004. Fiscal policy, business cycles and labor market fluctuations. Hungarian National Bank, working paper 2004-06.

[4] Bils, M., Klenow, P., 2004. Some evidence on the importance of sticky prices. Journal of Political Economy 112, 947-985.

[5] Blanchard, O., Perotti, R., 2002. An empirical characterization of the dynamic effects of changes in government spending and taxes on output. Quarterly Journal of Economics 117, 1329-68.

[6] Blanchard, O., Gali, J., 2007. Real wage rigidities and the New Keynesian model. Journal of Money, Credit and Banking 39, 33-65.

[7] Bouakez, H., Rebei, N., 2007. Why does private consumption rise after a government spending shock? Canadian Journal of Economics 40, 954-979.

[8] Burnside, C., Eichenbaum, M., Fisher, J., 2004. Fiscal shocks and their consequences. Journal of Economic Theory 115, 89-117.

[9] Calvo, G., 1983. Staggered prices in a utility maximizing framework. Journal of Monetary Economics 12, 383-398.

[10] Christiano, L., 2005. Firm-specific capital and aggregate inflation dynamics in the Woodford's model. Manuscript available at http://faculty.wcas.northwestern.edu/~lchrist/research.htm

[11] Christiano L., Eichenbaum, M., Evans, C., 2005. Nominal rigidities and the dynamic effects of a shock to monetary policy. Journal of Political Economy 113, 1-45.

[12] Christiano, L., Fisher, J., 2003. Stock market and investment good prices: implications for macroeconomics. NBER working paper 10031.

[13] Colciago, A., 2007. Rule-of-thumb consumers, equilibrium determinacy and the effect of government spending shocks. Wage stickiness matters. Manuscript University of Milano-Bicocca, available at http://ideas.repec.org/p/pra/mprapa/3275.html

[14] Danthine, J., Donaldson, J., 2002. A note on NNS models: introducing physical capital; avoiding rationing. Economic Letters 77, 433-437.

[15] Eichenbaum, M., Fisher, J., 2005. Evaluating Calvo-style sticky price models. Manuscript.

[16] Erceg, C., Henderson, D. W., Levin, A., 2000. Optimal monetary policy with staggered wage and price contracts. Journal of Monetary Economics 46, 381-413.

[17] Faruqee, H., Laxton, D., Muir, M., Pesenti, P., 2006. Would protectionism diffuse global imbalances and spur economic activity? A scenario analysis. NBER working paper 12704.

[18] Fatas, A., Mihov, I., 2001. The effects of fiscal policy on consumption and employment: theory and evidence. Manuscript.

[19] Furlanetto, F., Seneca, M., 2007a. Rule-of-thumb consumers, productivity and hours. Manuscript Norges Bank, available at http://www.norges-bank.no/research/furlanetto/

[20] Furlanetto, F., Seneca, M., 2007b. Fiscal shocks and real rigidities. Manuscript Norges Bank, available at http://www.norges-bank.no/research/furlanetto/

[21] Galí, J., 1999. Technology, employment and the business cycle: do technology shocks explain aggregate fluctuations? American Economic Review 89, 249-271.

[22] Gali, J., Gertler, M., Lopez-Salido, D., 2001. European inflation dynamics. European Economic Review 45, 1237-1270.

[23] Gali, J., Lopez-Salido, D., Valles, J., 2007. Understanding the effects of government spending on consumption. Journal of the European Economic Association 5, 227-270.

[24] Gali, J., Monacelli, T., 2005. Monetary policy and exchange rate volatility in a small open economy. Review of Economic Studies 72, 707-734.

[25] Gilchrist S., Himmelberg, C., 1995. Evidence on the role of cash flow for investment. Journal of Monetary Economics 36, 541-572.

[26] Ireland, P., 2003. Endogenous Money or Sticky Prices? Journal of Monetary Economics 50, 1623-1648.

[27] King, R., Watson, M., 1996. Money, prices, interest rates and the business cycle. Review of Economics and Statistics 78, 35-53.

[28] Linnemann, L., 2006. The effect of government spending on private consumption: a puzzle? Journal of Money, Credit and Banking 38, 1715-1736.

[29] Linnemann, L., Schabert, A., 2003. Fiscal policy in the New Neoclassical synthesis. Journal of Money, Credit and Banking 36, 151-175.

[30] Linnemann, L., Schabert, A., 2006. Productive government expenditure in monetary business cycle models. Scottish Journal of Political Economy 53, 28-46.

[31] Mankiw, G., 2000. Macroeconomics. Textbook, Worth Publishers.

[32] Mankiw, G., 2000. The savers-spenders theory of fiscal policy. American Economic Review, 90, 120-125.

[33] Mountford, A., Uhlig, H., 2002. What are the effects of fiscal policy shocks? CEPR working paper 3338.

[34] Nakamura, E., Steinsson, J., 2007. Five facts about prices: a reevaluation of menu cost models. Manuscript Harvard University.

[35] Natvik, G., 2007. Government spending with rule-of-thumb consumers and steady state inequality. Manuscript, Norges Bank.

[36] Perotti, R., 2005. Estimating the effects of fiscal policy in OECD countries. CEPR working paper 4842.

[37] Rotemberg, J., 1982. Sticky prices in the United States. Journal of Political Economy 90, 1187-1211.

[38] Schmitt-Grohe, S., Uribe, M., 2006. Comparing two variants of Calvo-type wage stickiness. NBER working paper 12740.

[39] Sveen, T., Weinke, L., 2005. New perspectives on capital, sticky prices, and the Taylor principle. Journal of Economic Theory 123, 21-39.

[40] Sveen, T., Weinke, L., 2007. Firm-specific capital, nominal rigidities and the Taylor principle. Journal of Economic Theory 127, 729-737.

[41] Woodford, M., 2003. Interest and prices: foundations of a theory of monetary policy. Princeton University Press.

[42] Woodford, M., 2005. Firm-specific capital and the New Keynesian Phillips curve. International Journal of Central Banking 1, 1-46.

Appendix

In this appendix we extend the baseline model letting each household choose its wage under adjustments costs à la Rotemberg. Each household supplies one variety of labor indexed by z and is a monopolistic competitor on this market.

Firms. Each firm, indexed by j, aggregates ROT and OPT labor in the following way:

$$N_t(j) = \left[(\lambda)^{\frac{1}{\varepsilon_w}} N_t^r(j)^{1-\frac{1}{\varepsilon_w}} + (1-\lambda)^{\frac{1}{\varepsilon_w}} N_t^o(j)^{1-\frac{1}{\varepsilon_w}} \right]^{\frac{\varepsilon_w}{\varepsilon_w - 1}} \tag{24}$$

where ε_w denotes the elasticity of substitution between the two labor bundles that are defined as follows:

$$N_t^r(j) = \left[\left(\frac{1}{\lambda} \right)^{\frac{1}{\varepsilon_{wr}}} \int_{(1-\lambda)}^{1} N_t^r(j,z)^{1-\frac{1}{\varepsilon_{wr}}} dz \right]^{\frac{\varepsilon_{wr}}{\varepsilon_{wr}-1}} \tag{25}$$

$$N_t^o(j) = \left[\left(\frac{1}{1-\lambda} \right)^{\frac{1}{\varepsilon_{wo}}} \int_{0}^{(1-\lambda)} N_t^o(j,z)^{1-\frac{1}{\varepsilon_{wo}}} dz \right]^{\frac{\varepsilon_{wo}}{\varepsilon_{wo}-1}} \tag{26}$$

$N_t^o(j)$ denotes the quantity of OPT labor used by the firm in the production process, $N_t^o(j,z)$ is the quantity of OPT labor of variety z and ε_{wo} is the elasticity of substitution between different varieties of OPT labor. The same notation is used for ROT agents.

The wage indexes corresponding to the labor bundles (25) and (26) are given by the following aggregators:

$$W_t^r = \left[\frac{1}{\lambda} \int_{(1-\lambda)}^{1} W_t^r(z)^{1-\varepsilon_{wr}} dz \right]^{\frac{1}{1-\varepsilon_{wr}}} W_t^o = \left[\frac{1}{1-\lambda} \int_{0}^{1-\lambda} W_t^o(z)^{1-\varepsilon_{wo}} dz \right]^{\frac{1}{1-\varepsilon_{wo}}}$$

Each firm takes the wages $W_t^r(z)$ and $W_t^o(z)$ as given and chooses the optimal demand for each labor variety by minimizing costs subject to the aggregation constraints (25) and (26). The demand functions for each variety of both kinds of labor read as follows:

$$N_t^r(j,z) = \frac{1}{\lambda}\left(\frac{W_t^r(z)}{W_t^r}\right)^{-\varepsilon_{wr}} N_t^r(j) \tag{27}$$

$$N_t^o(j,z) = \frac{1}{1-\lambda}\left(\frac{W_t^o(z)}{W_t^o}\right)^{-\varepsilon_{wo}} N_t^o(j) \tag{28}$$

Next, taking the wage indexes W_t^r and W_t^o as given, each firm chooses the optimal demand for the two labor bundles $N_t^r(j)$ and $N_t^o(j)$ by minimizing labor costs subject to (24). This yields the following demand functions for labor bundles:

$$N_t^r(j) = \left(\frac{W_t^r}{W_t}\right)^{-\varepsilon_w} \lambda N_t(j)$$

$$N_t^o(j) = \left(\frac{W_t^o}{W_t}\right)^{-\varepsilon_w} (1-\lambda) N_t(j)$$

and the aggregate wage index is defined as:

$$W_t = \left[\lambda W_t^{r1-\varepsilon_w} + (1-\lambda) W_t^{o1-\varepsilon_w}\right]^{\frac{1}{1-\varepsilon_w}}$$

Households. OPT households maximize

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[U^o\left(C_t^o, N_t^o(z)\right)\right] \tag{29}$$

subject to the budget constraint and labor demand (obtained aggregating (28) across firms):[8]

$$P_t\left(C_t^o+I_t^o\right)+R_t^{-1}B_{t+1}^o+P_tT_t^o+F_t^o=W_t^o\left(z\right)N_t^o\left(z\right)+R_t^kK_t^o+B_t^o+D_t^o \quad (30)$$

$$N_t^o\left(z\right)=\frac{1}{1-\lambda}\left(\frac{W_t^o\left(z\right)}{W_t^o}\right)^{-\varepsilon_{wo}}N_t^o \quad (31)$$

The first-order condition with respect to $W_t^o\left(z\right)$ reads as follows:

$$\begin{aligned} 0 &= \left(\frac{1}{C_t^o}\right)\frac{W_t^o}{P_t}\left[\frac{\varepsilon_{wo}}{1-\lambda}-1+\phi_{wo}\left(\Pi_t^{wo}-1\right)\Pi_t^{wo}\right] \\ &\quad -\frac{\varepsilon_{wo}}{1-\lambda}\left(N_t^o\right)^{\varphi}-\beta E_t\left[\frac{1}{C_{t+1}^o}\phi_w\left(\Pi_{t+1}^{wo}-1\right)\Pi_{t+1}^{wo}\frac{W_{t+1}^o}{P_{t+1}}\frac{N_{t+1}^o}{N_t^o}\right] \end{aligned} \quad (32)$$

where Π_t^{ow} denotes OPT wage inflation.

ROT households solve a static problem maximizing:

$$U^r\left(C_t^r,N_t^r\left(z\right)\right)=\log C_t^r-\frac{N_t^r\left(z\right)^{1+\varphi}}{1+\varphi}$$

subject to the budget constraint and labor demand (derived aggregating (27) across firms):

[8] Even if in equilibrium aggregate hours and wages (N_t, W_t) and individual variety hours and wages $(N_t\left(z\right), W_t\left(z\right))$ are equal, ex-ante it is not the case. Therefore, when we write the maximization problem we index hours and wages to variety z. For sake of simplicity, we dont make this distinction for the other variables.

$$P_tC_t^r + P_tT_t^r + F_t^r = W_t^r(z)\,N_t^r(z)$$

$$N_t^r(z) = \frac{1}{\lambda}\left(\frac{W_t^r(z)}{W_t^r}\right)^{-\varepsilon_{wr}} N_t^r$$

The static FOC with respect to $W_t^r(z)$ is given by

$$0 = \left(\frac{1}{C_t^r}\right)\frac{W_t^r}{P_t}\left[\frac{\varepsilon_{wr}}{\lambda} - 1 + \phi_{wr}\left(\Pi_t^{wr} - 1\right)\Pi_t^{wr}\right] - \frac{\varepsilon_{wr}}{1-\lambda}N_t^{r\varphi} \tag{33}$$

The log-linearized model. The extended model is log-linearized around the same steady state as the baseline model: hence, in steady state all agents share the same wages, hours worked and consumption levels. Tax rates are set accordingly. The wage setting equations are given by log-linearized versions of (32) and (33):

$$\pi_t^{wo} = \beta E_t \pi_{t+1}^{wo} - \kappa_{wo}\left(rw_t^o - c_t^o - \varphi n_t^o\right)$$

$$\pi_t^{wr} = -\kappa_{wr}\left(rw_t^r - c_t^r - \varphi n_t^r\right)$$

where $\kappa_{wo} = \frac{\frac{\varepsilon_{wo}}{1-\lambda}-1}{\phi_{wo}}$ and $\kappa_{wr} = \frac{\frac{\varepsilon_{wr}}{\lambda}-1}{\phi_{wr}}$. For simplicity we impose $\varepsilon_w = \varepsilon_{wr} = \varepsilon_{wo} = 4$. We calibrate ϕ_{wo} and ϕ_{wr} to be consistent with 4 quarters of wage rigidity in the Calvo model. Thus, $\phi_{wo} = \frac{\frac{\varepsilon_{wo}}{1-\lambda}-1}{(1-\beta\theta_w)(1-\theta_w)\theta_w^{-1}(1+\varphi\varepsilon_w)^{-1}}$, $\phi_{wr} = \frac{\frac{\varepsilon_{wr}}{\lambda}-1}{(1-\beta\theta_w)(1-\theta_w)\theta_w^{-1}(1+\varphi\varepsilon_w)^{-1}}$ and $\theta_w = 0.75$.

Figure 1 Key Results in GLV (2007)

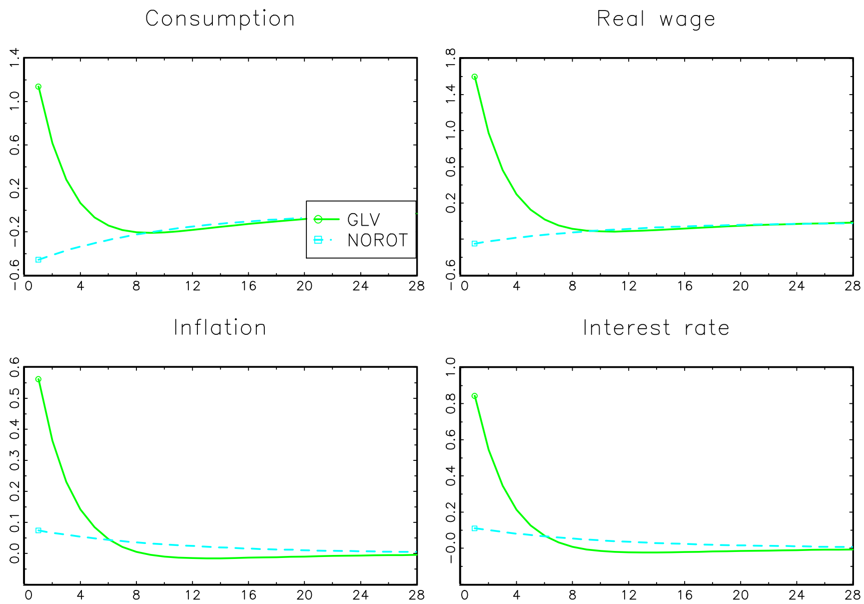

Figure 2 GLV Model + Sticky Wages

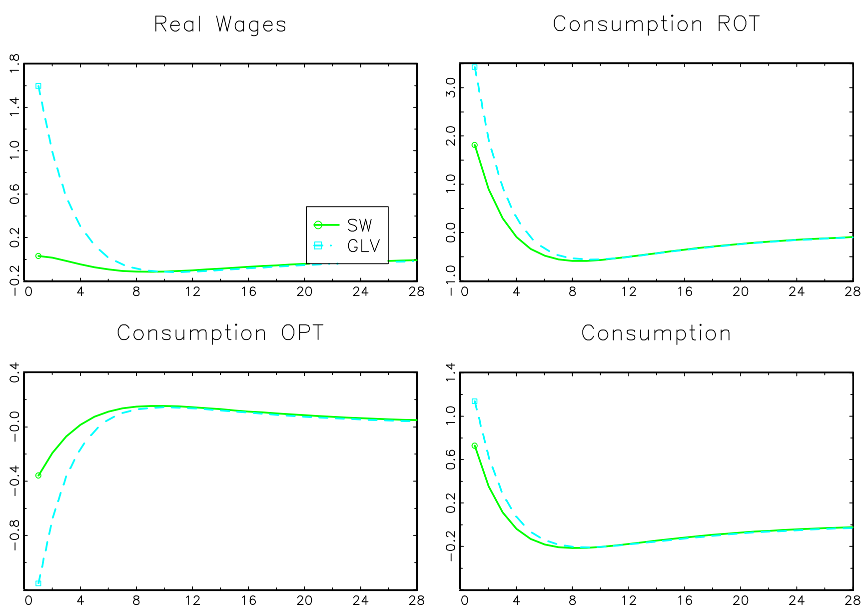

Figure 3 GLV Model + Sticky Wages

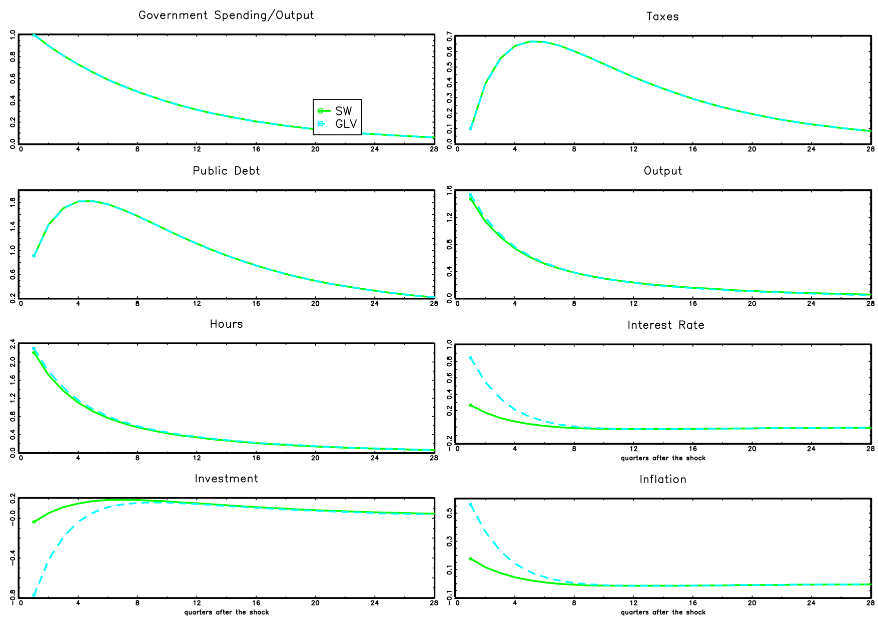

Figure 4 Sensitivity Analysis

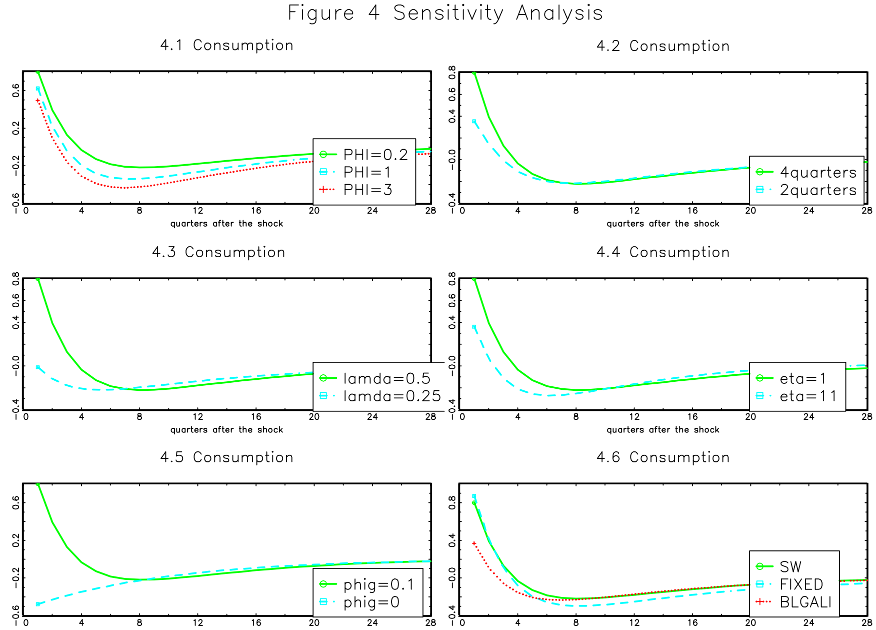

Figure 5 GLV Model + Sticky Wages + Firm−Specific Capital

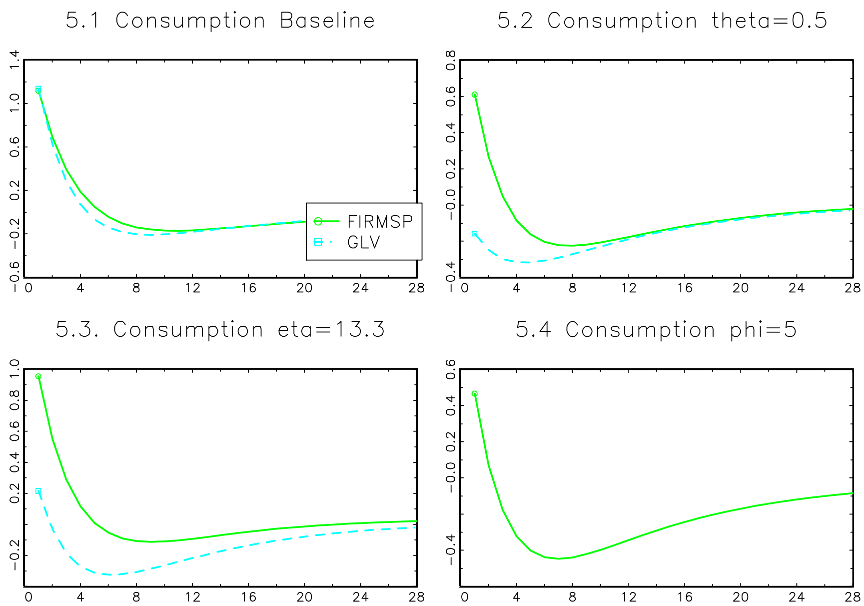

Figure 6 The Model with Heterogeneity in Wages