Fiscal Shocks and the Consumption Response when Wages are Sticky

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Abstract

In this paper we study the impact of government spending shocks on aggregate consumption building on the GLV (Gali, Lopez-Salido, Valles (2005)) model. We show that the GLV model implies a counterfactual increase in the real wage. The introduction of sticky wages, that by construction solves this problem, preserves the main result of their paper, i.e. the positive response of consumption. Furthermore, the introduction of firm specific capital in this model, not only describes the capital accumulation process in a more realistic way, but allows to reproduce a positive response of consumption under only two quarters of price stickiness instead of four.

1 Introduction and motivation

The creation of huge budget deficits in the United States and the debate on the usefulness of strict budgetary rules in the European Union have renewed the interest on the effectiveness of government spending shocks as a stabilization tool. The emergence of some empirical evidence based on Vector Autoregressions (VAR) (Perotti (2005) among many others[1]) should help the researchers to understand the impact of these shocks and to discriminate among different economic models. To achieve this goal, the response of private consumption to a government spending shock is the empirical moment that has attracted the bulk of the interest in the literature because Keynesian models and neoclassical models forecast opposite dynamics for this variable. Keynesian models, based on the IS-LM framework, forecast a positive response of consumption whereas neoclassical models, based on the RBC framework, imply a negative response. Somewhat surprisingly, the cited empirical evidence tends to favor the Keynesian model: all the papers

[1]A non exaustive list includes: Blanchard and Perotti (2002), Fatas and Mihov (2002), Gali, Lopez-Salido and Valles (2005), Burnside, Eichenbaum and Fisher (2003), Edelberg, Eichenbaum and Fisher (1999), Mountford and Uhlig (2000).

cited above found a positive and significant response of consumption, at least in the United States, even though the paper of Perotti (2005) 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: the New Keynesian literature introduces monopolistic competition and sticky prices in the RBC model but these ingredients, that are very useful to study other questions[2], are not sufficient to reproduce plausible dynamics in the case of fiscal shocks (Linnemann and Shabert (2003)).

One way to obtain a positive response of consumption has been suggested by Gali, Lopez-Salido and Valles (GLV)(2005). They add a non standard feature to the basic New Keynesian model: the presence of "rule of thumb consumers" (ROT). These agents consume each period their current disposable income and do not save; they coexist with optimizing agents (OPT) who take consumption decisions according to the "permanent income hypothesis". Optimizing agents are more sophisticated because they can hold bonds and they receive profits deriving from firms ownership. The presence of rule of thumb agents is crucial because it is a very simple device to break Ricardian equivalence: since they do not optimize intertemporally, it matters for them if 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, the great advantage of this model is that it allows us to study the impact of fiscal shocks that are not budget balanced, i.e. the kind of fiscal shocks that is more plausible in reality[3].

A government spending shock financed, at least in part, through a budget deficit, affects the two types of consumers in a different way. On one hand OPT consumers reduce their consumption because they rationally anticipate that taxes will increase sooner or later. On the other hand ROT consumers can increase consumption if their current income increases. As we will explain in detail in the paper, this is the case in a model with deficit financing, sticky prices and monopolistic competition in the labor market. The response of aggregate consumption can be positive if the positive response of ROT consumption is bigger than the negative response of OPT consumption. In GLV (2005) this is the case and they can reproduce a positive response of aggregate consumption.

However, this result relies on a big increase in the real wage that pushes up current income of ROT consumers and this is not a desirable property of their model because this huge positive response of the real wage is counterfactual. The evidence on the response of real wages conditional to govern-

[2]Monopolistic competition and sticky prices are key ingredients to study the effects of monetary shocks (Gali (2003)).

[3]The VAR literature shows that in general government spending shocks are never budget balanced (see, among others, Corsetti and Müller (2005)).

ment spending shocks favors a very limited response: in Fatas and Mihov (2002) the maximum response of the real wage ia 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 huge reaction of the real wage is not consistent with the "Lucas less famous critique", saying that real wages are roughly acyclical. We know that real wages are procyclical responding to productivity shocks. If they are procyclical also with respect to government spending shock, it seems difficult to reproduce the aggregate acyclicality that is observed in the data. The introduction of wage stickiness in the model, by construction, prevents the counterfactual swing in this variable. However, wage rigiditity under the form of sticky wages could make it difficult to confirm the result of GLV because it prevents the big increase in current income that pushes up ROT consumption.

A second criticism that can be raised to the GLV model concerns the capital accumulation process: in GLV households rent capital to firms that can freely exchange capital on the rental market. A more realistic alternative is given by a model where firms own their capital stock and increase (or decrease) it through the investment decision.

The objective of this paper is to address these two points introducing sticky wages (that by construction prevent the counterfactual huge response of the real wage) and firm specific capital in the GLV model. We could think that the successful result of GLV heavily relies on this counterfactual increase in the real wages and that it could not be robust to the introduction of a more realistic modelization of the labor market. However, the main result of the paper is that this intuition is not correct: a model with sticky wages preserves the crowding-in of consumption and the GLV result is strongly confirmed under more restrictive conditions.

The mechanism is the following: as we expected, the nominal wage rigidity implies that wage inflation is much lower and thus also the reaction of the real wage is low (it is almost fixed). This in fact lowers the increase in ROT consumption because current income increases less. 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 the consumption decision by OPT agents and the investment decision by firms: both decline less than the flexible wage case. It happens that for realistic calibrations the two effects have almost the same size and thus the result of GLV is preserved.

Furthermore, a second important result is derived: the combined effect of sticky wages and firm specific capital preserves the positive effect on consumption under a significantly lower degree of price stickiness (two quarters instead of four), thus being consistent with some recent empirical evidence provided by Bils and Klenow (2004) and Klenow and Krystov (2005)

The rest of the paper is composed as follows: in section 2 we propose a review of the literature on this field, in section 3 we present the model, in section 4 we show the results of our numerical simulations, in section 5 we discuss the consistence of the model with the possible causes of the decline in effectiveness of fiscal shocks as shown by Perotti (2005), in section 6 we conclude.

2 Review of the literature

Most of the recent literature on fiscal policy in Dynamic Stochastic General Equilibrium (DSGE) models has been motivated by the empirical evidence. The general message of the empirical papers is that fiscal shocks have a positive and significant effect on output and consumption, a positive but not significant effect on real wages whereas the evidence on prices and investment is mixed. Perotti (2005) remarks that these results are affected by instability and a structural break can be identified around 1980. In the last 20 years the effects of fiscal shocks are much less expansionary but still, at least from a qualitative point of view, the results are confirmed.[4]

The traditional RBC model has at least two problems to replicate these effects: it is not able to reproduce a positive effect on consumption and a positive response of the real wage. Baxter and King (1993) look at the effects of various fiscal shocks in the baseline RBC model and find a negative response of consumption and real wages. The underlying mechanism is known as the "wealth effect". In this model agents reduce consumption and increase labor supply because they anticipate an increase in taxes to finance the increase in government spending. Output multipliers are generally low and can even be negative in case of distortionary taxation.

Linnemann and Shabert (2003) look at the effects of a government spending shock in a New-Keynesian model with sticky prices à la Calvo, monopolistic competition and lumps sum taxation where Ricardian equivalence holds. In this model the wealth effect is still present but is accompanied by a demand effect due to price stickiness: demand for goods increases because prices are sticky, labor demand is derived from goods demand and increases as well. Both effects increase output. The wealth effect has a negative effect on consumption while the demand effect has a positive impact but the former is always higher. The response of real wages is ambiguous and depends

[4] These results refer to the case of USA, arelatively closed economy. From a qualitative point of view they are confirmed in more open economies (Perotti (2005), Corsetti and Müller (2005). However, from a quantitative point of view, the multipliers are lower in more open economies: this is consistent with the predictions of New Keynesian open economy models (Furlanetto (2006)).

on the relative strength of the two effects. In general investment decreases. The expansionary effect of a government spending depends on the monetary policy rule: an aggressive rule limits the expansionary effect and in general produces an output multiplier lower than one. Thus the standard New Keynesian model with a public sector can reproduce a positive response of real wages but cannot replicate the response of consumption.

To achieve this goal, four solutions have been proposed. The first solution is to include government spending in the utility function as a complement of private consumption. This has been done by Bouakez and Rebei (2004) in the RBC framework: if the complementarity effect is big enough it is possible to induce a positive response of consumption, even though the result depends crucially on the calibration of the coeffcient of risk aversion. They estimate the model using maximum likelihood techniques and find evidence of complementarity. A second possible solution is to consider productive government spending, i.e. putting government spending in the production function (Linnemann and Shabert (2005)). The introduction of productive government spending has two main effects: a demand effect, because an increase in government spending implies a higher demand for labor and capital that increases the marginal cost, and a supply effect, because the government spending shock behaves as a productivity shocks and has a cost alleviating effect on the marginal cost. If the supply effect is bigger than the demand effect the marginal cost decreases and the interest rate decreases as well through the interest rate rule. A decrease in the interest rate implies, through the Euler equation an increase in consumption; however the result depends on the government spending/output ratio, that weights the demand effect, and on the production elasticity of government spending, that weights the supply effect. Linnemann (2006) proposes a third way to obtain a positive response of consumption: a non additively separable utility function of the form $\frac{1}{1-\sigma}c_t^{1-\sigma}n_t^{1+\varphi}$ and a small intertemporal elasticity of substitution in consumption guarantee a positive response of consumption in the baseline RBC model. The mechanism is the following: the negative wealth effect pushes agents to increase labor supply and, given that consumption and hours worked are complements in the utility function, this raises the marginal utility of consumption. It turns out that for a wide variety of plausible calibrations the complementarity effect can overturn the negative wealth effect on private consumption.

A fourth way to reproduce the evidence on consumption is the introduction of rule of thumb consumers in the new Keynesian model and that is the way chosen by GLV. The introduction of rule of thumb consumers in dynamic macroeconomic models has been suggested by Mankiw (2000) 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. Thus, they consume each period their current income and they cannot save[5]. An increase in public spending implies a positive effect on current income because of the increase both in hours worked (through the wealth effect) and in the real wage (through sticky prices). Hence, rule of thumb consumers can consume more and compensate the decrease in consumption by optimizing agents.[6] This result heavily relies on a big increase in the real wage that is obtained only through departures from perfect competition in the labor market. In figure 1 we can see how the introduction of ROT agents changes crucially the response of these key variables: the blue line represents the results in the traditional New Keynesian model (thus with 100% of OPT agents), the green line shows the results in the same model (with the same calibration) but with 50% of OPT agents and 50% of ROT agents.

As said in the introduction, we propose the introduction of sticky wages and firm-specific capital in the GLV model to avoid the counterfactual increase in the real wage and to model the capital accumulation process in a more realistic way. We think that both ingredients are important in a DSGE model and we show that both strongly confirms the results of GLV(2005).

Sticky wages, in the form popularized by Calvo (1983), can correct for the big increase in real wages because, by construction, they prevent huge swings in nominal wages. In the literature we can find many other arguments to justify the insertion of sticky wages in our model. Probably, the most convincing is in Christiano, Eichenbaum, Evans (CEE) (2005): according to their results, sticky wages are essential to reproduce plausible dynamics in aggregate variables responding to a wide variety of economic shocks. CEE find a strong evidence in favor of sticky wages and they estimate a degree of nominal wage rigidity much higher than the degree of price rigidity. Sticky wages have been introduced by Erceg, Henderson and Levin (2000): they study the impact of a monetary policy shock and show that the form of the New Keynesian Phillips curve is modified to include a cost push shock that implies a trade-off between output and price inflation stabilization. Since then, sticky wages have become a standard ingredient of DSGE model but, as far as we know, the analysis of fiscal shocks and sticky wages has not been studied yet.

Firm-specific capital is a recent development in the literature that studies capital accumulation in the New Keynesian model. One obvious reason to introduce firm-specific capital is for sake of realism: the assumption of firm-specific capital is much more appealing than the rental rate assumption.

[5]To appreciate the empirical relevance of ROT behavior see Bilbiie (2005) and the references therein.

[6]We think that the arguments of Mankiw to call for the introduction of ROT agents in DSGE models are convincing. However, we insist on the fact that ROT agents are a simple device to break Ricardian equivalence and to study the effects of fiscal shocks financed by an increase in deficit. Of course, an endogenous, rather than exogenous, mechanism to determine the percentage of ROT agents would be a great improvement in the model.

As shown by Danthine and Donaldson (2002), the rental rate assumption is innocuous in the RBC framework because the models are isomorphic; but 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 recently their price). Danthine and Donaldson 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 a recent literature that introduces firm-specific capital in the New Keynesian framework seems very promising. Under rental rate capital the marginal cost is common across firms and intermediate good producers can freely exchange capital on the rental market: there, firms with high demand can acquire more capital that becomes immediately productive up to the point where all firms have the same capital/labor ratio. 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 adjustements. It turns out that the marginal cost depends on economic 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 reoptimze its price will plan to raise it. However, the rise in price would reduce output, that 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 the capital was not predetermined. This implies that the marginal cost is less reactive to aggregate shocks and thus these shocks have a bigger effect on quantities and a lower effect on prices.

Sveen and Weinke (2005), Woodford (2005) and Nolan and Thoenissen (2005) exploit the expansionary properties of firm-specific capital and suggest us a second deep reason to introduce firm-specific capital in the model: it allows us to obtain realistic dynamics in output and consumption for a lower degree of price stickiness. The papers cited above look at the interactions with productivity and monetary shocks but the link with fiscal shock, as far as we know, has not been explored yet. However, with respect to each shock, the mechanism is always the same: firm-specific capital increases the degree of real rigidity in the model and implies a more expansionary effect of the shocks. In this paper we show that this is the case also with respect to government spending shock; in fact, we confirm the result of GLV for a much lower degree of price rigidity (two quarters instead of four).

3 The model

The economy is composed of a continuum of households and a continuum of firms producing intermediate goods that are transformed in 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 is allowed to run public deficits at least over some time horizon. 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.

3.1 Households

The model is composed of a continuum of agents of measure $[0,1]$: a fraction $[0,\lambda]$, the "rule of thumb agents", consumes each period its disposable income and a fraction $(\lambda,1]$, the "optimizing", optmizes intertemporally and behaves according to the permanent income hypothesis. The generic household is indexed by $i\in[0,1]$.

3.1.1 Optimizing households

Optimizing households, indexed by the superscript o, derive utility from consumption (C_t^o) and disutilty from hours worked (N_t^o) and they maximize the sum of expected future utilities discounted at the rate of time preference β :

$$E_0\sum_{t=0}^{\infty}\beta^t\left[U\left(C_t^o,N_t^o\right)+V\left(G_t\right)\right] \tag{1}$$

subject to the sequence of budget constraints:

$$P_tC_t^o+R_t^{-1}B_{t+1}^o+P_tT_t^o=W_tN_t^o+B_t^o+D_t^o \tag{2}$$

where P_t is a price index, R_t is the gross nominal interest rate, B_t is the quantity of one-period, riskless, nominal bonds and $P_tT_t^o$ is the amount of lump-sum taxes that has to be payed in period t. On the right-hand side of the budget constraint we have the three sources of income for a typical household: labor income ($W_tN_t^o$), bond holdings paying one unit of the consumption index in period t (B_t^o) and dividends derived from the ownership of monopolistically competitive firms (D_t^o). Agents derive utility from government spending but for simplicity utility is separable with respect to consumption.[7]

The per-period utility is common to all consumers and is given by:

[7]The fact that G_t appears in the utility function in an additively separable way implies that it does not influence the choice of the households. Hence the model is technically equivalent to a model where government spending is a pure waste.

$$U(C,L) = \log C - \frac{N^{1+\varphi}}{1+\varphi} \quad (3)$$

where φ is a parameter ≥ 0.

The household maximizes over consumption and bold holdings. Its choice is summarized by the following Euler equation.

$$\beta \left(\frac{C_{t+1}^{o}}{C_{t}^{o}} \right) \left(\frac{P_t}{P_{t+1}} \right) = Q_{t,t+1} \quad (4)$$

where $Q_{t,t+1}$ is the stochastic discount factor for nominal payments. It is linked to the gross nominal interest rate by the following condition: $R_t^{-1} = E_t\ Q_{t,t+1}$. 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 will be sufficiently high to insure that both type of households will be willing to supply the quantity of labor demanded by firms.

3.1.2 Rule of thumb agents

Rule of thumb agents, indexed by the superscript r, have the same preferences as optimizing consumers but they do not choose consumption intertemporally. They simply consume each period their disposable income::

$$P_t C_t^r = W_t N_t^r - P_t T_t^r \quad (5)$$

Rule of thumb agents differ from optimizing agents because they cannot smooth consumption through bonds holdings and because they do not receive dividends.

3.1.3 Aggregation

Aggregate consumption is given by the weighted average of both kind of consumption where the weight is given by the percentage of rule of thumb consumers (λ) in the economy:

$$C_t = \lambda C_t^r + (1-\lambda) C_t^o \quad (6)$$

The same for aggregate hours:

$$N_t = \lambda N_t^r + (1-\lambda) N_t^o \quad (7)$$

3.2 Firms

3.2.1 Final good producers

The final good is produced by a perfectly competitive firm that packages intermediate inputs in a final output through a constant returns to scale technology. The production function is given by:

$$Y_t = \left(\int_0^1 Y_t^d \left(j \right)^{\frac{\epsilon_p - 1}{\epsilon_p}} dj \right)^{\frac{\epsilon_p}{\epsilon_p - 1}} \tag{8}$$

where ε_p represents the elasticity of substitution among intermediate goods.

Profit maximization and the assumption of perfect competition imply the following set of demand schedules:

$$Y_t^d \left(j \right) = \left(\frac{P_t \left(j \right)}{P_t} \right)^{-\epsilon_p} Y_t \tag{9}$$

where $P_t \left(j \right)$ represents the price of good produced by firm j where the continuum of goods is indexed by $j \in [0, 1]$. The zero-profit condition implies that the price index is $P_t = \left(\int_0^1 P_t \left(j \right)^{1-\epsilon_p} dj \right)^{\frac{1}{1-\epsilon_p}}$.

3.2.2 Intermediate goods producers

A typical monopolistically competitive firm maximizes the sum of expected future discounted profits:

$$\max \sum_{k=0}^{\infty} E_t \left\{ Q_{t,t+k} \left[P_{t+k} \left(j \right) Y_{t+k}^d \left(j \right) - W_{t+k} N_{t+k} \left(j \right) - P_{t+k} I_{t+k} \left(j \right) \right] \right\} \tag{10}$$

where $I_t \left(j \right)$ represents investment made by firm j. It sets contingency plans for $\left\{ P_{t+k}^* \left(j \right), N_{t+k} \left(j \right), K_{t+k+1} \left(j \right) \right\}$ subject to a set of constraints:

$$\begin{aligned}
P_{t+k+1} \left(j \right) &= \left\{ \begin{array}{c} P_{t+k+1}^* \left(j \right) \text{ with probability } \left(1 - \theta_p \right) \\ P_{t+k} \left(j \right) \text{ with probability } \theta_p \end{array} \right\} && (11) \\
Y_{t+k}^d \left(j \right) &= \left(\frac{P_t \left(j \right)}{P_t} \right)^{-\epsilon_p} Y_{t+k} && (12) \\
Y_{t+k}^d \left(j \right) &\leq K_{t+k} \left(j \right)^{\alpha} N_{t+k} \left(j \right)^{1-\alpha} && (13) \\
N_{t+k} \left(j \right) &= \left[\int_0^1 N_{t+k,j} \left(z \right)^{\frac{\varepsilon_w - 1}{\varepsilon_w}} dz \right]^{\frac{\varepsilon_w}{\varepsilon_w - 1}} && (14) \\
I_{t+k} \left(j \right) &= \phi \left(\frac{I_{t+k} \left(j \right)}{K_{t+k} \left(j \right)} \right) K_{t+k} \left(j \right) && (15)
\end{aligned}$$

Prices are set according to a Calvo mechanism[8]: a time t price setter chooses the price for its good $P_t(j)$ equal to $P_t^*(j)$, being $P_t^*(j)$ the price that maximizes the discounted value of dividends over the expected duration of the selected price (and thus taking into account that this price will stay in place next period with probability θ_p and that the firm will be allowed to reoptimize with probability $(1-\theta_p)$). Firm j is monopolistically competitive on the market for its good and thus is constrained also by the demand curve for good j (12).

The firm chooses also the quantity of hours worked subject to the technological constraint given by the Cobb-Douglas production function (13). Constraint (14) represents the fact that firm j needs all the z types of labor to produce its intermediate good and describes how the z types of labor are used .

The last objective is to choose optimally investment $I_{t+k}(j)$, and in that way $K_{t+k+1}(j)$ because $K_{t+k}(j)$ is taken as given: the maximization with respect to investment is subject to constraint (15) that represents in a compact way the capital accumulation process. Investment becomes productive with a one period delay and is subject to adjustment costs: the function ϕ represents these costs and is increasing and convex. We assume, following Woodford (2003) and borrowing the notation from Sveen and Weinke (2004 and 2005), $\phi(1)=\delta$, $\phi'(1)=1$, and $\phi''(1)=\varepsilon_\psi$ where δ is the depreciation rate and ε_ψ measures the capital adjustment costs. As shown in Eichenbaum and Fisher (2005) ε_ψ is related to the elasticity of the investment to capital ratio with respect to Tobin's Q evaluated in steady state: for our model this elasticity is equal to $1/\delta\varepsilon_\psi$.

We obtain three first order conditions (FOC) from the maximization problem above. The first represents the price setting equation

$$\sum_{k=0}^{\infty}\theta_p^k E_t\left\{Q_{t,t+k}Y_{t+k}^d(j)\left[P_t^*(j)-\mu_p MC_{t+k}(j)\right]\right\}=0 \tag{16}$$

where $\mu_p=\frac{\epsilon}{\epsilon-1}$ represents the mark-up that would be charged in the case of flexible prices and MC is the firm nominal marginal cost given by:

$$MC_t(j)=\frac{W_t}{MPN_t(j)} \tag{17}$$

where $MPN(j)$ denotes firm j marginal product of labor.

The outcome of the maximization with respect to labor is a set of demand schedules for different types of labor given by:

$$N_{t,j}(z)=\left(\frac{W_t(z)}{W_t}\right)^{-\varepsilon_w}N_{t,j} \tag{18}$$

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

where ε_w represents the elasticity of substitution between the z different kinds of labor. The implicit assumption is that a fraction λ of workers of type z is composed by rule of thumb consumers and the rest by optimizing consumers. The second assumption is that the firm is indifferent between rule of thumb and optimizing consumers and thus allocate labor demand proportionally.

Through aggregation we obtain:

$$N_t(z) = \left(\frac{W_t(z)}{W_t}\right)^{-\varepsilon_w} N_t \tag{19}$$

The third FOC is associated with the investment decision

$$\frac{dI_t(j)}{dK_{t+1}(j)} P_t = E_t \left\{ Q_{t,t+1} \left[MS_{t+1}(j) - \frac{dI_{t+1}(j)}{dK_{t+1}(j)} P_{t+1} \right] \right\} \tag{20}$$

where the following holds true

$$MS_t(j) = W_t \frac{MPK_t(j)}{MPN_t(j)} \tag{21}$$

where $MPK(j)$ denotes firm j marginal product of capital.

As emphasized by Woodford (2005) and Sveen and Weinke (2005), this equation is very similar to rental rate case except for one detail. It is expressed in terms of the nominal marginal saving $MS_t(j)$, the reduction in the labor cost to produce a given quantity of output (determined by the demand) when the capital stock is increased by one unit.[9]

3.3 Monetary policy

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

$$r_t = r + \phi_\pi \pi_t \tag{22}$$

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 rule is already expressed in loglinear form.

3.4 Fiscal policy

The government has to satisfy the following budget constraint:

$$P_t T_t + R_t^{-1} B_{t+1} = B_t + P_t G_t \tag{23}$$

[9] In a model with rental capital, the rental rate of capital would take the place of the marginal saving in the same equation.

where $T_t = \lambda T_t^r + (1-\lambda) T_t^o$.

The government is allowed to run public deficits and set taxes according to the fiscal rule:

$$t_t = \phi_b b_t + \phi_g g_t \tag{24}$$

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 that express the weight that the fiscal authority accords to debt and current government spending. To avoid explosive debt dynamics we impose $\phi_b > \frac{\rho}{1+\rho}$ being $\rho = \frac{1}{\beta} - 1$. In the limiting case of $\phi_g = 1$ there is no deficit creation but Ricardian equivalence would still not hold: in that case ROT consumers would cut consumption more than OPT consumers because their current income would diminish a lot, while OPT agents would smooth the shock over future consumption.

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

$$g_t = \rho_g g_{t-1} + \epsilon_t \tag{25}$$

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

3.5 Unions

In the model wages are negotiated by a continuum of unions of measure $[0, x]$, indexed by z. In eachach union a percentage λ is given by ROT agents and consequentely the rest $(1-\lambda)$ is given by OPT agents.

The crucial assumption to simplify the derivation of the wage schedule is that each union allocates labor demand uniformly across ROT and OPT agents. This assumption is a useful device to impose the same wage for all agents of type z. The wage index is given by $W_t = \left(\int_0^x W_t(z)^{1-\epsilon_w} dz\right)^{\frac{1}{1-\epsilon_w}}$ where ε_w represents the elasticity of substitution across labor types. A typical union maximizes the following objective function:

$$\sum_{k=0}^{\infty} \theta_w^k E_t Q_{t,t+k} \left\{ \lambda \left[\frac{1}{C_{t+k}^r(z)} \frac{W_t^*(z)}{P_{t+k}} N_{t+k}(z) \right] + (1-\lambda) \left[\frac{1}{C_{t+k}^o(z)} \frac{W_t^*(z)}{P_{t+k}} N_{t+k}(z) \right] - \frac{N_{t+k}^{1+\varphi}(z)}{1+\varphi} \right\} \tag{26}$$

subject to the labor demand schedule for workers of type z (19) and taking into account that wages will stay in place for k periods with a probability θ_w^k according to same Calvo mechanism shown above in the case of price setting.

The FOC with respect to $W_t^*(z)$ is given by:

$$\sum_{k=0}^{\infty} \theta_w^k E_t Q_{t,t+k} \left[\frac{\lambda}{C_{t+k}^r (z)} + \frac{(1-\lambda)}{C_{t+k}^o (z)} + \frac{\epsilon_w}{1-\epsilon_w} \frac{N_{t+k}^{\varphi} (z)}{W_t (z) / P_{t+k}} \right] = 0 \qquad (27)$$

The objective function is standard in the New Keynesian literature with Calvo wages because it simplifies the derivation of the wage schedule. It depends positively on labor income weighted by marginal utility of consumption and negatively on the disutility of labor[10]. However, two considerations have to be made:

1) In the objective function above labor income is weighted by marginal utulity because, in general, $C_{t+k}^r (z) \neq C_{t+k}^o (z)$.

2) The unions take into account that firms allocate labor demand uniformly across different household types and hence $N_t^o (z) = N_t^r (z)$ for all t and all z. Unions are essential in the model to avoid different wages among type z agents: if household was free to choose its wage it would choose it as a mark up over its marginal rate of substitution. And given that consumption levels are different between ROT and OPT agents, marginal rates of substitution would be different as well and thus the wages would be different across ROT and OPT agents.

3.6 Market clearing

The clearing of labor and good markets requires for all t :

$$N_t = \int_0^1 N_t (j) \, dj \qquad (28)$$

$$Y_t (j) = Y_t^d (j) \text{ for all } j \qquad (29)$$

$$Y_t = C_t + I_t + G_t \qquad (30)$$

3.7 Steady state analysis

As GLV (2005) we look at a steady state with zero inflation, zero public debt and balanced primary deficit. To simplify the solution of the model it is convenient to impose $C^o = C^r$ and, given that our paper is interested in the dynamic responses to shocks and not in the characterization of the

[10] The objective function can be equivalently rewritten as $\sum_{k=0}^{\infty} \theta_w^k E_t \left\{ Q_{t,t+k} N_{t+k} (z) \left[\frac{W_t(z)}{P_{t+k}} - \left(\lambda MRS_{t+k}^r + (1-\lambda) MRS_{t+k}^o \right) \right] \right\}$. In that way it is transparent that the union seeks to fix the real wage as a mark up over a weighted average of the two marginal rates of substitution like the firm fixes its price as a mark-up over the marginal cost. The two representations yield the same loglinear first order condition.

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 therefore, to achieve the same steady state consumption, OPT agents must be taxed more than ROT agents. Under our baseline calibration the ratio T/Y is around 0.35 for OPT agents and around 0.03 for ROT agents[11]. Two alternative assumptions can insure $C^o = C^r$: 1) both kind of agents own firms and receive dividends (in that way agents are taxed at the same rate in steady state) 2) OPT agents subsidize ROT agents with a constant transfer (for an appropriate choice of the transfer steady state taxation is equal across agents). We underline the fact that the dynamics in the model are not affected by the assumption on steady state consumption.

3.8 Linearized equilibrium conditions

In this subsection we present the log-linear approximation of the optimality and market clearing conditions around a zero inflation steady-state. We use lower case letters to indicate log deviations from steady state (*i.e.*, $c_t = \log \frac{C_t}{C}$). Aggregate dynamics are represented by 8 endogenous control variables $(y_t, r_t, p_t, w_t, n_t, i_t, t_t)$, 2 endogenous state variables $\{b_{t+1}, k_{t+1}\}$ and 1 exogenous variable $\{g_t\}$.

Thus here we propose the eleven equilibrium conditions that we derived from the equations above.

The Euler equation for aggregate consumption is the only equation in the model that is influenced by the parameter λ. It is obtained from log-linearized versions of (4), (5) and (6) as shown in the appendix:

$$c_t = E_t c_{t+1} - (1-\lambda)(r_t - E_t \pi_{t+1}) - \Theta E_t \Delta n_{t+1} + \Theta_t E_t \Delta t^r_{t+1} - \Theta E_t \Delta rw_{t+1} \tag{31}$$

where $\Theta = \frac{\lambda\left(1-\alpha\frac{\delta}{1/\beta-1+\delta}\right)}{\gamma_c \mu_p}, \Theta_t = \frac{\lambda}{\gamma_c}$ and $rw_t = w_t - p_t$. Note that in the limiting case of $\lambda = 0$ the equation collapses to the traditional Euler equation.

From loglinearization of (16) we can derive a version of the New Keynesian Phillips curve (NKPC) for price inflation (π_t):

$$\pi_t = \beta E_t \pi_{t+1} + \kappa mc_t \tag{32}$$

The derivation of (32) is complex and the coefficient κ has to be computed numerically using a procedure developed by Woodford (2005) based on the method of undetermined coefficients[12]. The interested reader can find the complete derivation in Woodford (2005) and Sveen and Weinke (2005).

[11] In GLV (2005) the two ratios are around 0.44 and -0.05. Thus ROT agents receive a transfer in steady state. The difference with respect to our model is due to the capital accumulation process that in our model is firm specific.

[12] We thank Lutz Weinke for providing us with the code to compute the coefficient κ.

The presence of firm specific capital affects the coefficient κ: in particular the NKPC is flatter than the case with rental rate. Note that this is the only equation affected by firm-specific capital.

Loglinearizing equation (20) we find a differential equation for capital:

$$k_{t+1} = \Psi \left[\varepsilon_\psi k_t + \beta \varepsilon_\psi k_{t+2} + (1 - \beta (1 - \delta)) (E_t n_{t+1} + E_t r w_{t+1}) - (r_t - E_t \pi_{t+1}) \right] \tag{33}$$

where $\Psi = \frac{1}{\varepsilon_\psi (1+\beta) + 1 - \beta(1-\delta)}$.

Loglinearizing (27) we obtain the following New Keynesian Phillips curve for wage inflation (π_t^w) [13]:

$$\pi_t^w = \beta E_t \pi_{t+1}^w - \frac{(1-\theta_w)(1-\beta\theta_w)}{\theta_w (1 + \varphi \epsilon_w)} (r w_t - c_t - \varphi n_t) \tag{34}$$

Loglinearizing (13) and aggregating we obtain, up to a first order approximation, the following aggregate production function:

$$y_t = \alpha k_t + (1 - \alpha) n_t \tag{35}$$

Loglinearization of the market clearing condition (30) yields:

$$y_t = \gamma_c c_t + \gamma_I i_t + g_t \tag{36}$$

where $\gamma_c = \frac{C}{Y} = 1 - \gamma_I - \gamma_G$ and $\gamma_I = \frac{I}{Y} = \frac{\delta\alpha}{(\rho+\delta)\mu_p}$.

Monetary and fiscal policy rules are already given by equations (22) and (24).

We last with two equations that detail the evolution of the endogenous state variables:

$$k_{t+1} = \delta i_t + (1 - \delta) k_t \tag{37}$$

$$b_{t+1} = (1 + \rho)(b_t + g_t - t_t) \tag{38}$$

(37) is the loglinear approximation of (15) and (38) is derived from the government budget constraint linearized around a steady state with zero debt and a balanced primary deficit.

Equations (31) to (38), (22), (24) and (25) form a system of stochastic difference equations that can be solved using standard techniques in the DSGE literature.

[13] The detailed derivation can be found in the appendix.

4 Results

As a baseline calibration we choose the same values as GLV (2005). We made this choice to facilitate the comparability of the results. In the following sections we depart from the baseline calibration with respect to some crucial parameters.

The GLV calibration is summed up in the following table:

$\delta = 0.025$	$\alpha = 0.33$	$\varepsilon_\psi = 40$
$\beta = 0.99$	$\lambda = 0.5$	$\gamma_g = 0.2$
$\phi_\pi = 1.5$	$\phi_b = 0.33$	$\phi_g = 0.1$
$\varepsilon_p = 6$	$\theta_p = 0.75$	$\rho_g = 0.9$
$\varphi = 0.2$	$\theta_w = 0.75$	$\varepsilon_w = 4$

We need to fix a value for θ^w (the degree of wage stickiness) and ε_w (the elasticity of substitution between labor varieties) that are not present in GLV where wages are flexible. We choose θ^w equal to 0.75 (wages have an average duration of 4 quarters) and ε_w equal to 4 (the implied wage mark-up in the case of flexible wages is $\frac{\varepsilon_w}{\varepsilon_w - 1}$). ε_ψ equal to 40 corresponds to a unitary elasticity of investment to capital ratio with respect to Tobin's Q as in GLV(2005).

4.1 The effect of sticky wages

In figure 2 we can appreciate the effect of the introduction of sticky wages on the crucial variables under rental rate capital (we defer the introduction of firm specific capital to the next section to appreciate separetly the role of the different frictions)[14]: the red line (named GLV) represents the GLV model with flexible wages, the blue line (named SW) represents the extension with sticky wages. The size of the government spending shock is 1% of steady state output. In figure 2 we can observe the main result of this paper: even though the response of the real wage is flat, the consumption response is still positive. Why the effect on consumption is preserved? It is true that, as expected, lower wage inflation (implied by the wage stickiness) lowers the increase in ROT consumption, but a second effect goes in the opposite direction. In fact, lower wage inflation implies a lower increase in

[14] A model with rental rate capital (as GLV (2005)) differs with respect to a model with firm-specific capital in two dimensions:

1) the coefficient in the NKPC is higher and can be computed analitically: $\kappa^{firm\ specific} < \kappa^{rental\ rate} = \frac{(1-\beta\theta_p)(1-\theta_p)}{\theta_p}$

2) The ratio $\frac{WN}{PC}$ that is used in the loglinearized Euler equation is given by $\frac{1-\alpha}{\mu_p \gamma_c}$ whereas in a model with firm-specific capital is given by $\frac{1}{\gamma_C \mu_p}\left(1 - \frac{\alpha\delta}{\left(\frac{1}{\beta} - 1 + \delta\right)}\right)$ as shown in the appendix.

the marginal cost that in turn implies a lower increase in price inflation. But lower inflation has a crucial implication concerning monetary policy: lower inflation implies a lower increase in the interest rate by the central bank and a lower interest rate affects the consumption choice by OPT agents and the investment decision by firms. It turns out that in this model the lower increase in the interest rate when wages are sticky, with respect to the case of flexible wages, has an expansionary effect on OPT consumption and investment. Hence, the response of aggregate consumption depends on the strength of the two effect: in our model the second (the interest rate effect) almost compensates the first (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 counterfactaul increase of the real wage but it is a more robust result that is preserved under more strict conditions.

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 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 is not 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 affects the spending multipliers. The impact of sticky wages is relevant on the other variables presented in figure 3: 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 positive) and the increase in aggregate demand pushes up output. Labor demand increases and hours follow this pattern because agents are willing to supply the quantity of labor demanded by firms.

We remark that the crowding out effect of government spending on investment, described in all textbooks in 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.

4.2 The effect of firm specific capital

In figures 2 and 3 we can evaluate the impact of firm specific capital in the model: the green line (FIRMSP) represents the model with sticky wages and firm specific capital, the blue line (SW) is the model with sticky wages and rental capital and the blue line (GLV) is the baseline calibration of GLV with flexible wages and rental capital. We see that firm specific capital reinforces the mechanism described above: both sticky wages and firm specific capital reduce the marginal cost reaction to a government spending shock and this real rigidity is translated in lower inflation and lower reaction by the monetary policy authority. The lower increase in the interest rate pushes up further OPT consumption and investment. The effect on output is bigger than in GLV due to the increase in investment and to the response of aggregate consumption that is even larger than in GLV. The main message from figures 2 and 3 is that the GLV result on consumption is reinforced under a more realistic modelization of the capital accumulation process: even in presence of wage rigidities the model is able to reproduce all the results in GLV without relying on the counterfactual increase in the real wage. An important difference with respect to GLV is that, for the chosen calibration, the response of investment is now positive.

The introduction of firm specific capital is even more relevant if we want to lower the degree of price stickiness in the model. The experiment is interesting because some recent empirical evidence casts doubts on such a high degree of price stickiness as four quarters. The papers of Bils and Klenow (2004) and Klenow and Krystov (2005) provide evidence in favor of only two quarters of price stickiness. As we can see from figure 4, under these more strict conditions, the GLV model is not able to generate a positive response of consumption whereas the model with sticky wages and firm specific capital can easily reproduce a positive response of consumption. The investment response is still positive (except for the first quarter) and the output multiplier is bigger than one. This result confirms the evidence provided in Woodford (2005), Sveen and Weinke (2005), Nolan and Thoenissen (2005) for productivity and monetary shocks: when capital is firm specific the marginal cost reacts less to aggregate shocks. In that way these shocks have a bigger impact on quantities and a lower impact on prices. The more expansionary impact of shocks allows the researcher to lower the degree of price stickiness in the model preserving realistic dynamics in the variables of interest.

To sum up, the introduction of firm specific capital not only improves the realism of the model but, combined with the effect of sticky wages that reinforce the same mechanism, preserves the positive response of consumption with a degree of price stickiness of only two quarters.

4.3 Sensitivity analysis

4.3.1 Form of the wage rigidity

In our baseline model we choose to introduce the nominal wage rigidity in the model through a Calvo mechanism. The point of this section is to show that the positive response of consumption is indipendent on the form of the wage rigidity. To see this point we consider the rather extreme case of an enoumous degree of nominal wage rigidity ($\theta_W = 0.99$) [15]: in figure 5 we can see that even in this case the positive response of consumption is preserved.

A second way to model wage rigidity can be found in Blanchard and Gali (2006). In this paper the authors assume that real wages react sluggishly to economic conditions as a consequence of some unmodelled rigidity in the labor market. They propose the following (admittedly ad-hoc) wage schedule modeled as a partal adjustment mechanism:

$$rw_t = \gamma rw_{t-1} + (1 - \gamma)(c_t + \varphi n_t) \tag{39}$$

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 5 we consider the extreme case of complete real wage rigidity ($\gamma = 1$) and a case of partial real wage rigidity ($\gamma = 0.75$). The response of consumption is still positive and hence our result is indipendent of the postulated wage rigidity (either nominal or real).[16]

Danthine and Kurmann (2004) introduce real wage rigidity in a DSGE model through a dynastic utility function that depends negatively on the level of effort provided by the family. The solution of the model provides an effort function that is increasing with respect to a social norm that depends on the level and the change in the real wage. Danthine and Kurmann (2004) using US data estimate the following wage schedule:

$$rw_t = 0.0348 n_t + 0.9912 rw_{t-1} \tag{40}$$

In figure 5 we see that using this form of real wage rigidity the response of consumption is still positive, even if admittedly lower that in the other cases.

4.3.2 Different calibrations

In figure 6 we conduct a sensitivity analysis on the impulse response functions for consumption and investment. We propose the richest version of the model, with firm-specific capital, sticky wages and a degree of price stickiness of two quarters[17].

[15] Consider that the average wage duration is given by $\frac{1}{1-\theta_w}$. This case is thus equivalent to a fixed nominal wage.

[16] Even if in this model nominal wage ridsidity and real wage rigidity share the same properties, it is not always the case. Blanchard and Gali (2006) show that they have different implications in the design of the optimal monetary policy: in particular under real wage rigidity it is not possible to stabilize at the same time output gap and inflation whereas it is the case under nominal wage rigidity (if inflation is considered as a weighted average of price inflation and wage inflation).

[17] We keep the other parameters at the value set by GLV to make the comparison easier.

The first parameter we consider is the percentage of rule of thumb consumers (λ): we see that thirty percent is enough to reproduce a positive response in consumption (but not in investment).

A crucial parameter is the elasticity of the investment to capital ratio with respect to Tobin's Q. In their baseline calibration GLV choose the value of 1 (corresponding to $\varepsilon_{\psi} = 40$), following the RBC literature (King and Watson (1996)). However, Woodford (2005) argues that once firm specific capital is introduced, it is more appropriate to infer a value for this parameter 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 (corresponding to $\varepsilon_{\psi} = 3$). However, this value is very high with respect to the estimates based on aggregate data (Christiano and Fisher (1998)): a low value of ε_{ψ} reduces the size of adjustment costs in investment and allows this variable to fluctate more. We see in the second line of figure 6 that even using this extreme calibration the positive response of consumption is preserved whereas, as a consequence of the lower degree of adjustment costs, the reaction of investment becomes strongly negative. Hence ε_{ψ} crucially affect the size of the response of investment whereas the sign of the response is mostly affected by the degree of price and wage rigidity, teh percentage of rule of thumb consumers and the assumption of firm specific capital.

In the third line 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 we have a budget balanced shock. In the baseline calibration the shock is almost entirely deficit financed. In the pictures we see that a budget balanced shock yields different results: the response of consumption becomes significantly negative. We insist on the fact that this model allows to study deficit financed shocks that have very different implication with respect to budget-balanced shocks: in a model with only Ricardian consumers this difference vanishes.

In the fourth line we see that a decline in persistence of the shock $\left(\rho_g\right)$ does not affect significantly the results.

In the fifth line we see that sticky wages are crucial to obtain a positive response of consumption (considering that the price stickiness is only of two quarters): however, we still obtain a positive response with only two quarters of wage stickiness.

5 Application: the decline in effectiveness of US fiscal policy

The main result of Perotti (2005) is that the effectiveness of fiscal shocks has declined in the US over the last twenty-five years. The multipliers on output and consumption are lower in 1980-2001 than in 1960-80 and the multiplier on investment switches sign from positive (in the first period) to negative (in the last period). In the literature two explanations have found some support:

1) An increase in asset market participation (corresponding to a decline in λ in our model).

2) A more aggressive monetary policy in the Volker-Greenspan period (corresponding to an increase in ϕ_π).

In other fields of the literature a structural break has been identified around 1980: Stock and Watson (2003) document a decline in the volatility of output, Clarida, Gali, Gertler (1998, 2000) show that monetary policy has become more aggressive against inflation in the Volcker-Greenspan period. According to Perotti (2005), around the same date we should explain also a decline in the effectiveness of fiscal policy.

In this section we slightly depart from the GLV calibration taking into account the main results of the preceding section. Thus we lower the degree of price stickiness to two quarters (instead of four) and we accept the Woodford's suggestion to base the calibration of the investment process on firm-specific data (hence we use $\varepsilon_\psi = 3$ instead of 40). We keep the others parameters at the baseline value.

In figure 6 we have already plotted the effect of a decline in the percentage of rule of thumb consumers from 0.5 to 0.3. In figure 7 we plot the effect of an increase in the inflation coefficient from 1.1 (period 1960-1980) to 1.5 (1980-2005). We see that, according to our model, both explanations can be consistent with a significant decline in the multipliers.

A third candidate is a decline in persistence in the government spending shock: our model is not consistent with this view because less persistence implies a lower wealth effect and thus a more expansionary effect of the shock. A fourth candidate is an increase in openness: we extended this model in a two-country version but the multipliers are not very sensitive to openness. Thus a higher openness of the economy can explain only to some extent the reduced effectiveness of fiscal shocks, at least for values of the parameters that are realistic for the US economy[18].

6 Conclusion

In this paper we show the response of macroeconomic variables after a government spending in a model where Ricardian equivalence does not hold. We build on GLV (2005) and we show that is possible to obtain a positive response of consumption, as observed in the data for the USA, avoiding a counterfactual increase in the real wage and with only two quarters of price stickiness instead of four.

[18] For a detailed analysis of fiscal shocks in small open economies, see Furlanetto (2006).

We can avoid the counterfactual increase in the real wage that is present in GLV (2005) by introducing sticky wages in the model. Even though the wage rigidity prevents the increase in current income of ROT consumers, aggregate consumption can still rise because a lower increase in the interest rate favors consumption from optimizing agents and investment.

We can lower the degree of price stickiness in the model because of the combined action of sticky wages and firm specific capital that both limit the response of the marginal cost to aggregate shocks.

The main message of the paper is that the GLV result is robust and that rule of thumb consumers are an important ingredient in DSGE models to explain fiscal shocks.

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Appendix

Derivation of equation (31)

We start from loglinearized versions of (5), (4) and (6)that are given by:

$$c_t^r = \frac{WN}{PC}\left(rw_t - n_t^r\right) - \frac{1}{\gamma_c} t_t^r \tag{41}$$

$$c_t^o = E_t c_{t+1}^o - \left(r_t - E_t \pi_{t+1}\right) \tag{42}$$

$$c_t = \lambda c_t^r + (1-\lambda)\, c_t^o \tag{43}$$

We apply the operator $\left(1 - L^{-1}\right)$ to (41) and (43) and we find:

$$c_t^r - E_t c_{t+1}^r = \frac{WN}{PC}(rw_t - E_t rw_{t+1}) - \frac{WN}{PC}(n_t^r - E_t n_{t+1}^r) - \frac{1}{\gamma_c}(t_t^r - E_t t_{t+1}^r) \tag{44}$$

$$c_t - E_t c_{t+1} = \lambda(c_t^r - E_t c_{t+1}^r) + (1-\lambda)\,(c_t^o - E_t c_{t+1}^o) \tag{45}$$

Substituting (44) and (42) into (45) we have:

$$c_t - E_t c_{t+1} = -\frac{\lambda WN}{PC}(\Delta E_t rw_{t+1} - \Delta E_t n_{t+1}^r) + \frac{\lambda}{\gamma_c}\Delta E_t t_{t+1}^r - (1-\lambda)\,(r_t - E_t \pi_{t+1}) \tag{46}$$

We need to calculate $\frac{WN}{PC}$. From an aggregate version of (10) we have an expression for aggregate profits (Π) :

$$\Pi = PY - WN - PI \tag{47}$$

and deviding by PY we have:

$$\frac{\Pi}{PY} = 1 - \frac{WN}{PY} - \gamma_I \tag{48}$$

In steady state $P = \left(\frac{\varepsilon}{\varepsilon-1}\right) MC$ and thus $\frac{\Pi}{PY} = \frac{1}{\varepsilon}$. From (20) and (21) evaluated in steady state we have $MS = \frac{1}{\beta} - 1 + \delta$ and $MS = \frac{\alpha\delta}{\mu_p \gamma_I}$: thus $\gamma_I = \frac{\alpha\delta}{\mu_p\left(\frac{1}{\beta}-1+\delta\right)}$. Putting these expressions in (48) we find that $\frac{WN}{PY} = \frac{1}{\mu_p}\left(1 - \frac{\alpha\delta}{\left(\frac{1}{\beta}-1+\delta\right)}\right)$ and hence $\frac{WN}{PC} = \frac{1}{\gamma_C \mu_p}\left(1 - \frac{\alpha\delta}{\left(\frac{1}{\beta}-1+\delta\right)}\right)$. Using this expression for $\frac{WN}{PC}$ and the fact that $n_t^r = n_t^o = n_t$ in equation (46) we obtain (31) in the main text.

Derivation of equation (33)

Using (4) and the assumptions on the function ϕ we find the loglinear version of (20):

$$k_{t+1}(j) = \frac{1}{1+\beta} k_t(j) + \frac{\beta}{1+\beta} k_{t+2}(j) + \frac{1-\beta(1-\delta)}{\varepsilon_\psi(1+\beta)} ms_{t+1}(j) - \frac{1}{\varepsilon_\psi(1+\beta)}(r_t - E_t \pi_{t+1}) \tag{49}$$

The loglinear approximation of (21) is given by:

$$ms_t(j) = ms_t - \frac{\varepsilon}{1-\alpha} p_t(j) - \frac{1}{1-\alpha} k_t(j) \tag{50}$$

where $ms_t = rw_t + n_t - k_t$ and ms_t denotes the real marginal saving.

Substituting (50) in (49) and averaging over all intermediate goods producers we obtain (33) in the text. We are allowed to average across firms because the first order condition with respect to investment is independent of whether a firm can reset or not its price.

Derivation of equation (34)

The law of motion for the wage index in log-linear terms reads:

$$w_t = \theta_w w_{t-1} + (1-\theta_w) w_t^* \tag{51}$$

The log-linear version of (27) is:

$$w_t^* = (1-\theta_w\beta) E_t \left[\sum_{k=0}^{\infty} (\theta_w\beta)^k (c_{t+k} + \varphi n_{t,t+k} - p_{t+k})\right] \tag{52}$$

where $n_{t,t+k}$ represents the quantity of labor supplied at time $t+k$ by a household that reset her wage at time t. From log-linearization of (19) :

$$n_{t,t+k} = -\varepsilon_w \left(w_t^* - w_{t+k}\right) + \varphi n_{t+k} \tag{53}$$

Substituting (53) and (52) into (51) and rearranging terms we obtain (34) in the main text. All the intermediate steps in the derivation can be found in Monacelli (2005).

Fig.1 key results in GLV (2005)

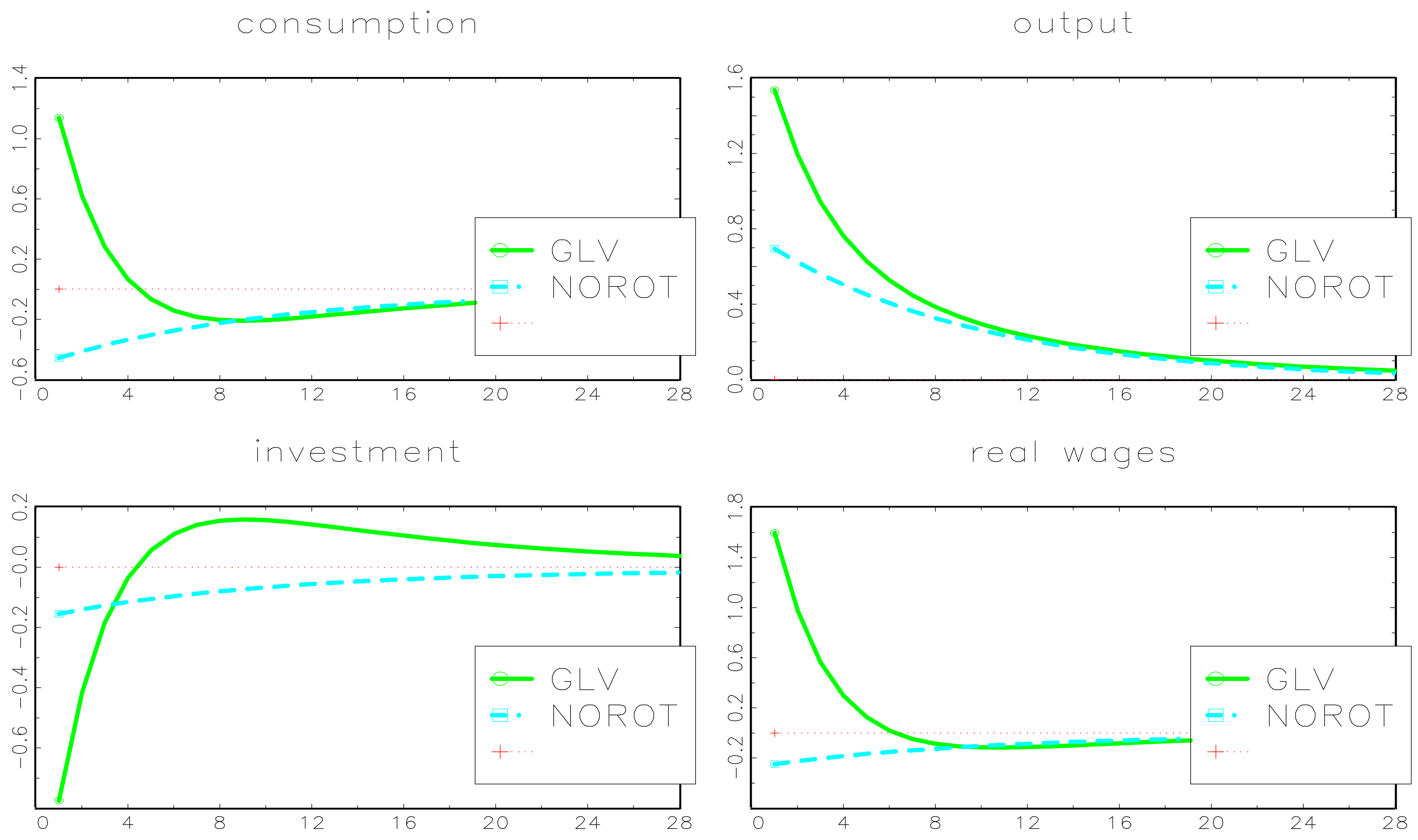

Fig.2 GLV model + sticky wages + firm-specific

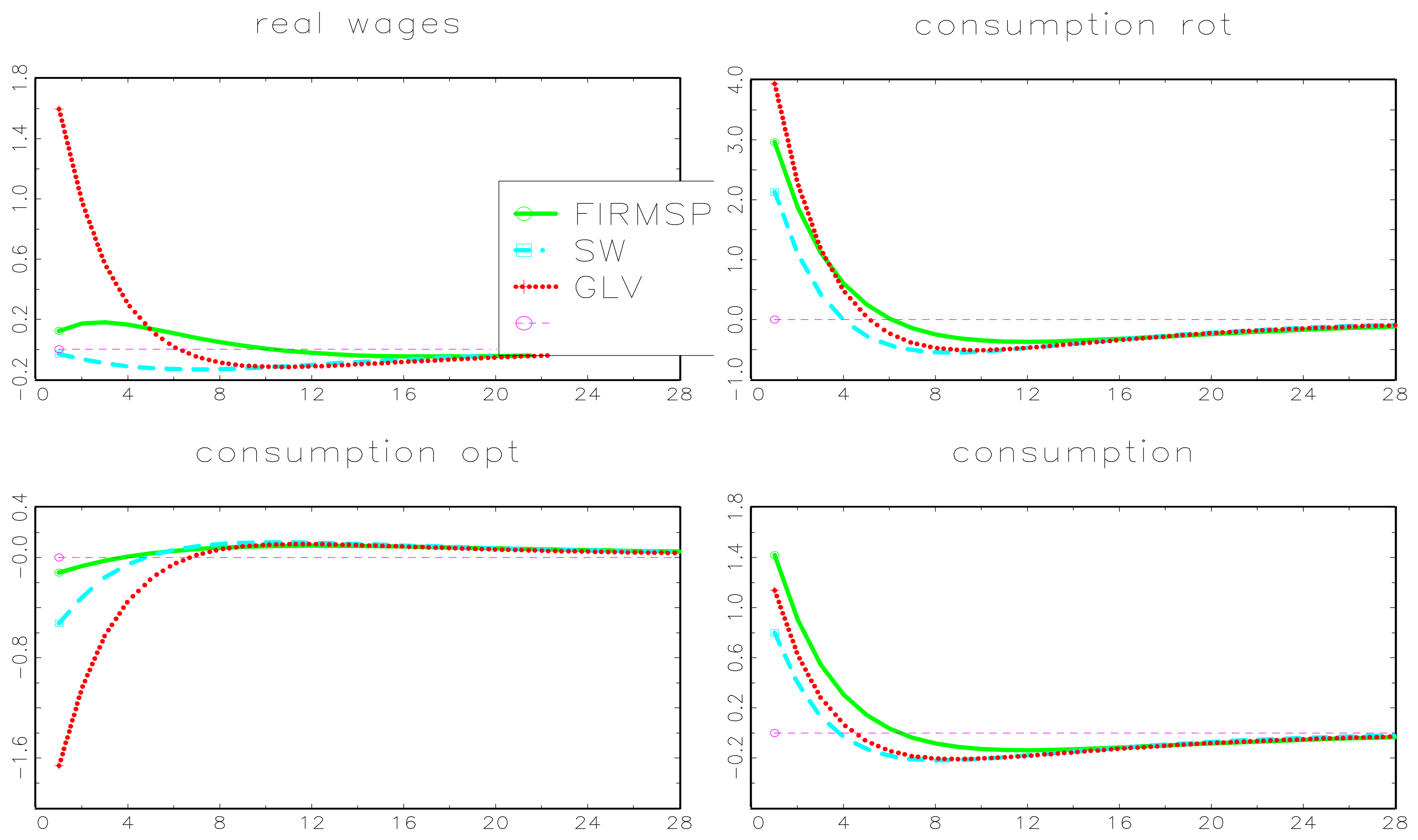

Fig.3 GLV model + sticky wages + firm−specific

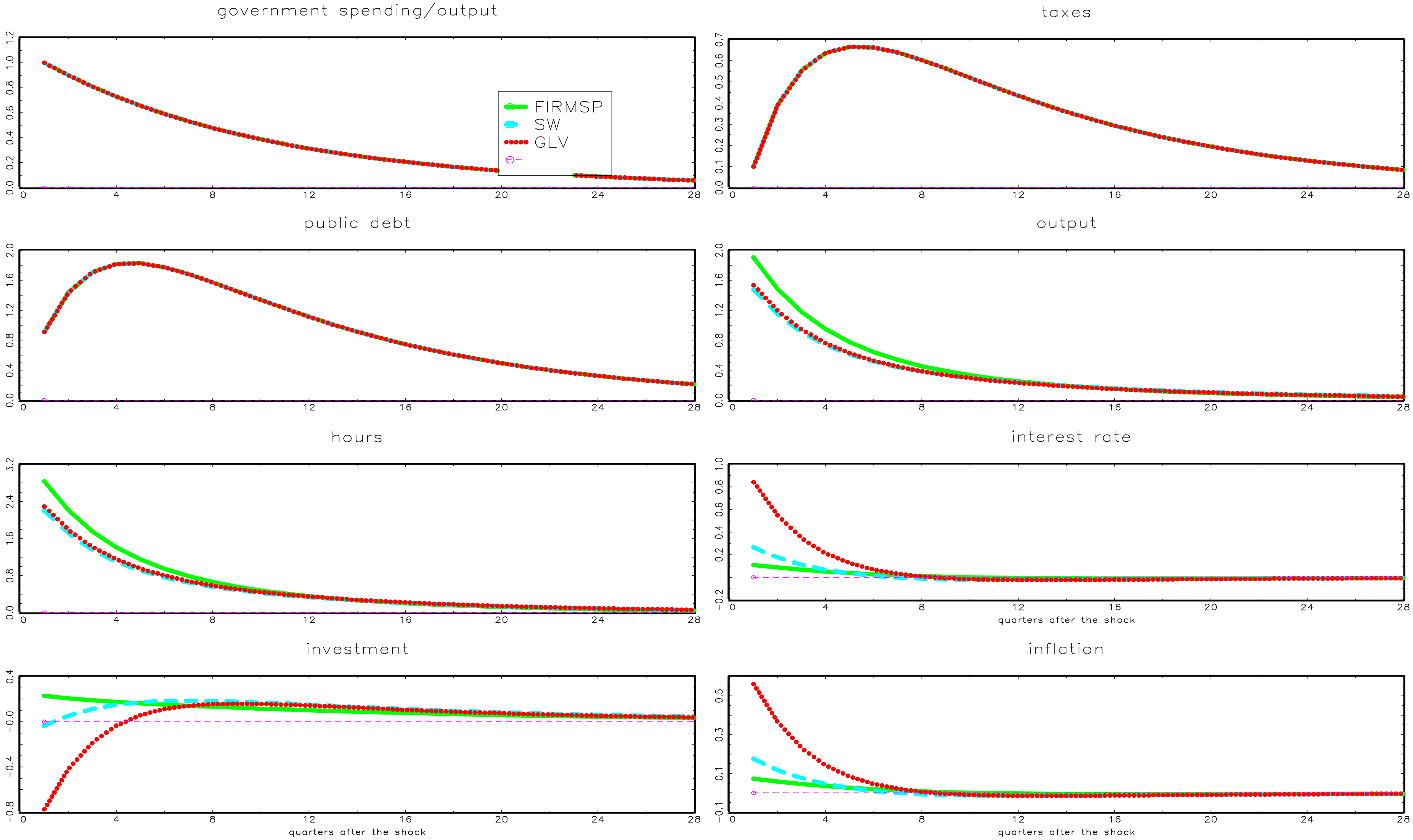

Fig.4 two periods of price stickiness

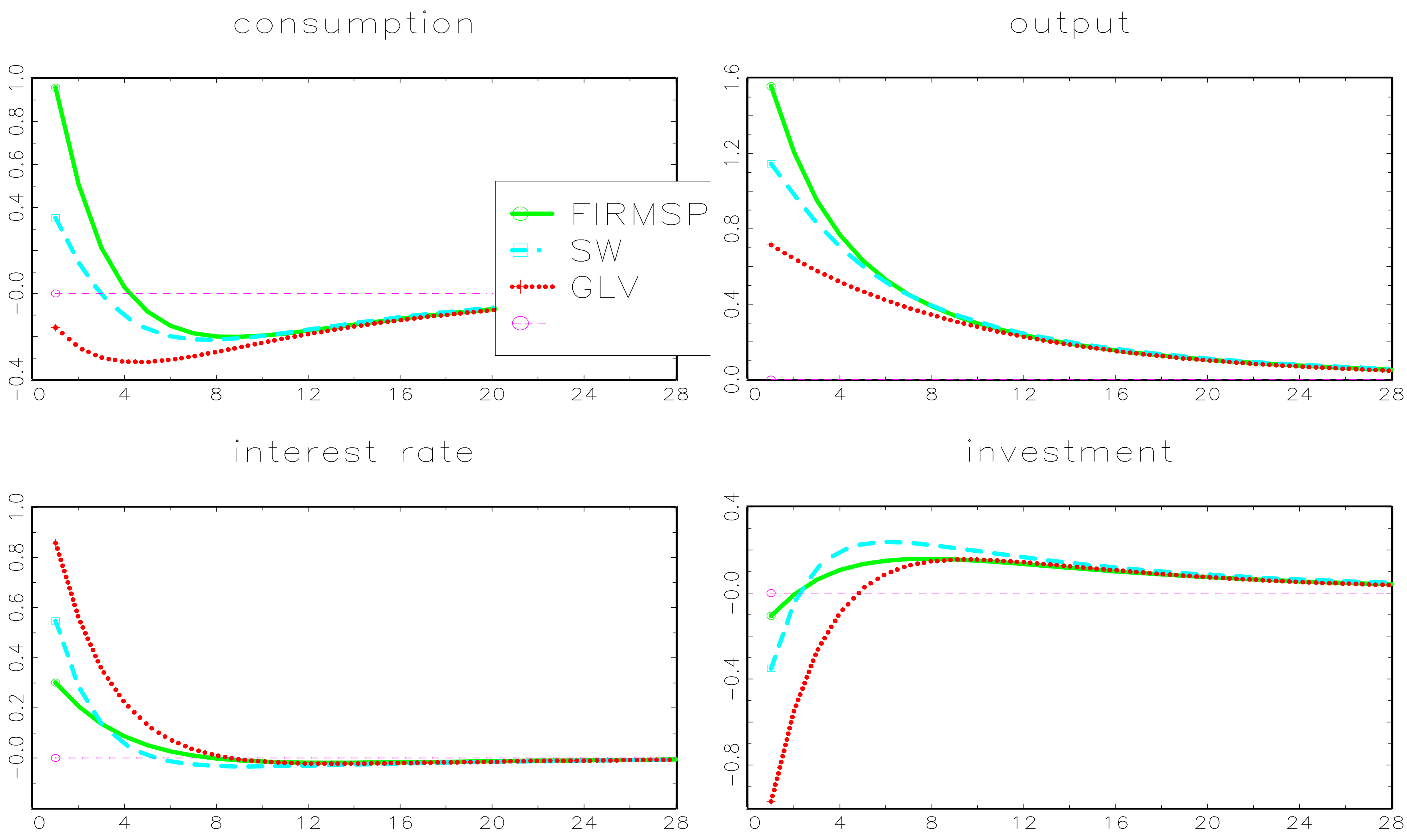

Fig.5 Different form of wage rigidity

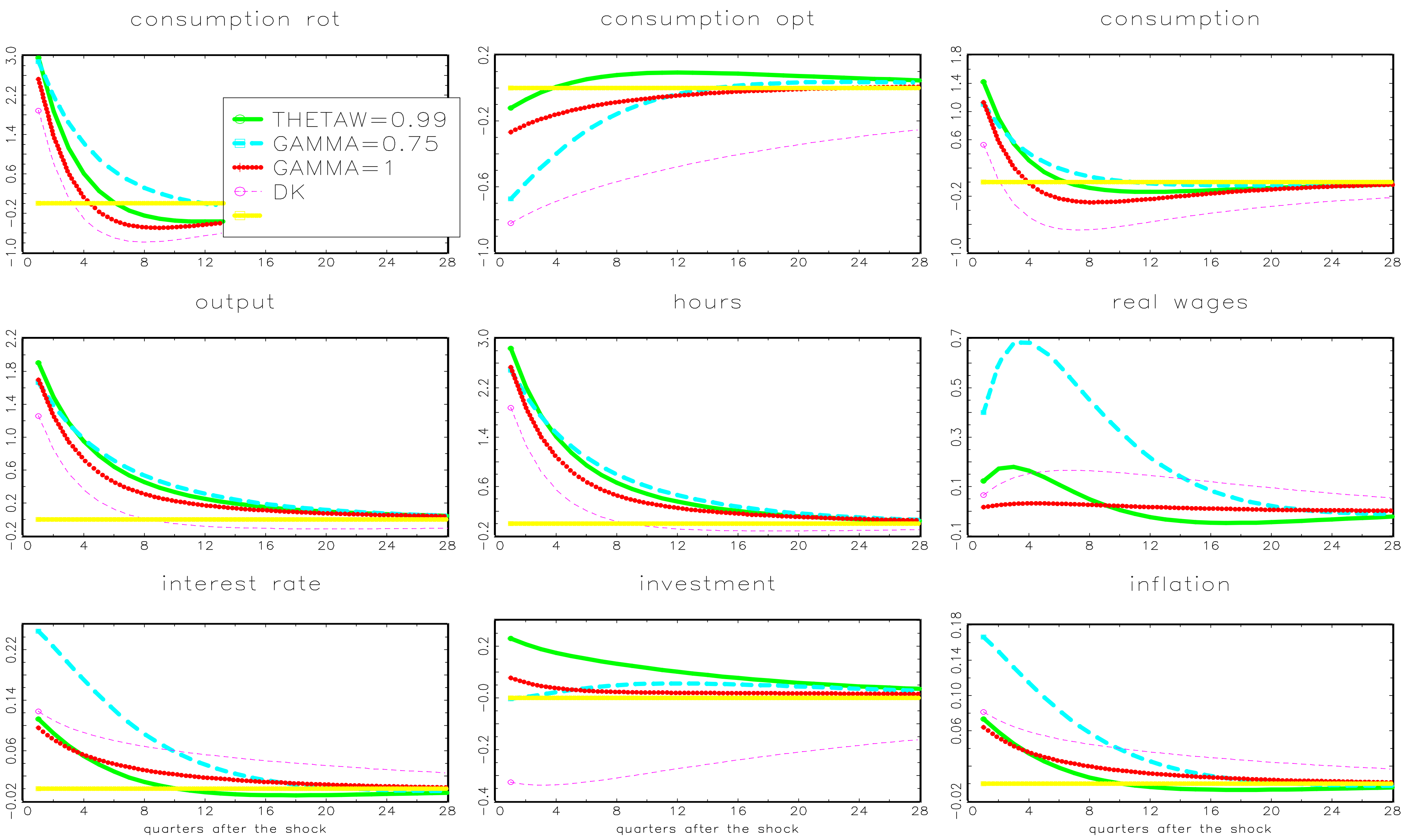

Fig.6 sensitivity analysis

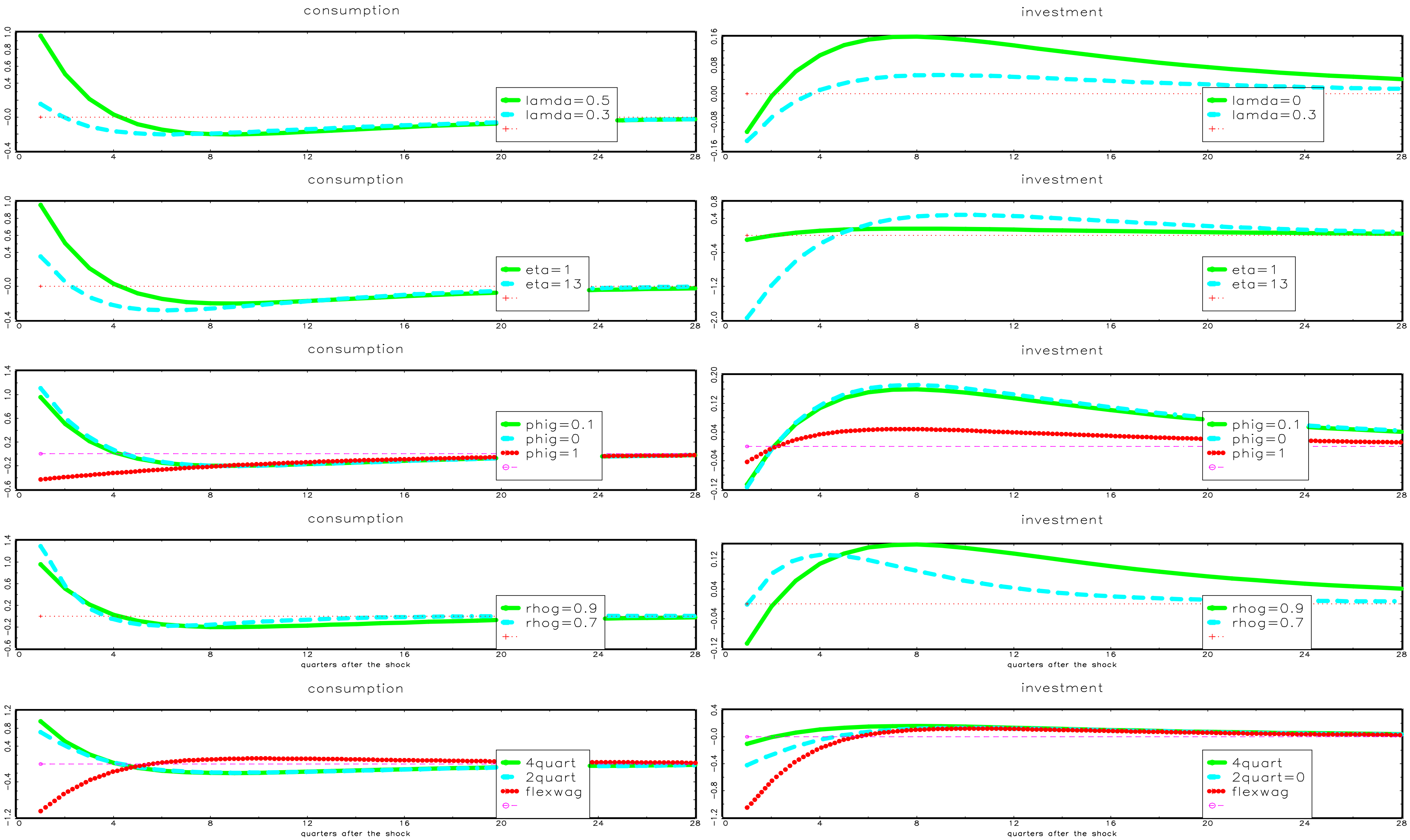

Fig.7 More or less aggressive monetary policy