The optimal inflation rate revisited[*]

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January, 2012

Abstract

We challenge the widely held belief that New-Keynesian models cannot predict optimal positive inflation rates. In fact these are justified by the Phelps argument that monetary financing can alleviate the burden of distortionary taxation. We obtain this result because, in contrast with previous contributions, our model accounts for the distortionary effects of public transfers and for consumption scale effects in the monetary transactions technology. We also contradict the view that the Ramsey policy should minimize inflation volatility and induce near-random walk dynamics of public debt in the long-run. In our model it should instead

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[*] The authors are grateful to Fabio Canova, Martin Ellison, Jordi Galì, Luca Onorante, Frank Smets and seminar participants at EC2 2011 Conference (EUI), National Bank of Poland, Universities of Milan Bicocca and Crete for useful comments on earlier drafts. The authors also acknowledge financial support by MIUR (PRIN).

stabilize debt-to-GDP ratios in order to mitigate steady-state distortions. Our results thus provide theoretical support to policy-oriented analyses which call for a reversal of debt accumulated in the aftermath of the 2008 financial crisis.

Jel codes: E52, E58, J51, E24.

Keywords: trend inflation, monetary and fiscal policy, Ramsey plan.

1 Introduction

Optimal monetary policy analyses (Khan *et al.*, 2003; Schmitt-Grohé and Uribe, SGU henceforth, 2004a) identify two key frictions driving the optimal level of long-run (or trend) inflation. The first one is the adjustment cost of goods prices, which invariably drives the optimal inflation rate to zero. The second one are monetary transaction costs that arise unless the central bank implements the Friedman rule, i.e. a negative steady-state inflation rate as long as the steady-state real interest rate is positive.

Phelps (1973) conjectured that to alleviate the burden of distortionary taxation it might be optimal for governments to resort to monetary financing, driving a wedge between the private and the social cost of money. However, SGU's (2004a) numerical simulations suggest that the optimal inflation rate lies between zero and the Friedman rule even accounting for the Phelps' effect. This conclusion carries over to the optimality of near-zero volatility of inflation and near random walk behavior in government debt and tax rates in response to shocks. A consensus therefore seems to exist that monetary transactions costs are relatively small at zero inflation, and that implementing low and stable inflation is the proper policy.[1]

This theoretical result is in sharp contrast with empirical evidence. For instance, both in the US and in the Euro area, average inflation rates over the 1970-1999 period have been close to 5%. Even the widespread central bank practice of adopting inflation targets between 2% and 4% is apparently at odds with theories of the optimal inflation rate (SGU, 2011). Furthermore, following

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[1] In their survey of the literature, SGU (2011) argue that the optimality of zero inflation is robust to other frictions, such as nominal wage adjustment costs, downward wage rigidity, hedonic prices, incompleteness of the tax system, the zero bound on the nominal interest rate.

the build up of large stocks of debt in the aftermath of the 2007-2008 financial crisis, some economists have argued that the public debt surge should be reversed and that a temporary increase in inflation might be necessary to achieve this goal. For instance Rogoff (2010) suggests that "two or three years of slightly elevated inflation strikes me as the best of many very bad options." Blanchard *et al.* point at the potential role of the inflation tax as one among several distortionary taxes which are available to policymakers. Aizenman and Marion (2009) predict that a 6% inflation rate would reduce the debt/GDP ratio by 20 percent within 4 years.

In the paper we reconsider the Phelps's effect and obtain results that challenge previous theoretical results. Our analysis suggests that a moderate inflation rate might indeed be optimal and that inflation (and tax rates) volatility should be exploited in order to stabilize debt/GDP ratios in the long run.

The starting point in our analysis is that dismissal of the Phelps' effect is due to an unrealistic parameterization for public expenditures and overall taxation. In the literature, standard calibrations of public expenditures focus on public consumption-to-GDP ratios, typically set at 20% (SGU, 2004a; Aruoba and Schorfeide, 2009). This follows a long-standing tradition in business cycle models, where only public consumption decisions have real effects. In our framework this choice is not correct, because the focus here is on distortionary financing of public expenditures in steady state, where also other components of public expenditure matter. As a matter of fact, public consumption accounts for a limited component of the overall public expenditures in OECD countries (Table 1).

Table 1

Even if a proportion of total expenditures goes into production subsidies, it is apparent that distortionary taxation substantially exceeds public consumption, in order to finance redistributive policies. For instance in the US, according to the National Accounts (NIPA) data, in the 1998-2008 period government transfer payments and government purchases respectively were close to 12% and 15% of GDP. Oh and Reis (2011) document that between 2008 and 2009 three quarters of the US huge fiscal stimulus in response to the financial crisis were due to increases in transfers.

We show that just allowing for a plausible parameterization of public transfers to households in the SGU (2004a) model reverses their conclusion about the optimal inflation rate, which now monotonically increases from 2% to 12% as the transfers-to-GDP ratio goes from 10% to 20%. We also find that an identical increase in the public-consumption-to-GDP ratio would have a negligible impact on the optimal inflation rate. So, what is special about public transfers? To grasp the intuition behind our result, assume that lump-sum taxes can be used to finance expenditures. In the case of public transfers the overall effect on the household budget constraint is nil, and labor-consumption decisions are unchanged. By contrast, an increase in public consumption generates a negative wealth effect that raises the labor supply. If lump sum taxes are not available, the different wealth effect explains why financing transfers requires higher tax rates than financing an identical amount of public consumption. Since the incentive to monetary financing is increasing in the amount of tax distortions, this also explains why the optimal financing mix requires stronger reliance on inflation when we take transfers into account. Our result is robust to the inclusion of nominal wage rigidity, and is strengthened when we allow for a moderate degree of price and wage indexation (20%).

We then extend the model by introducing consumption scale effects in the monetary transactions technology, in line with existing theoretical models (Baumol, 1952; Khan *et al.*, 2003) and with empirical evidence (Attanasio *et al.*, 2002). We find that such consumption scale effects unambiguously contribute to raise the optimal inflation rate. The intuition behind this result is simple. An increase in inflation allows a reduction in distortionary taxation but raises the monetary transactions costs. This latter effect is weakened when the transaction cost is inversely related to the amount of consumption, which, in turn, increases if the tax rate falls.

In contrast with received wisdom on the optimality of zero-inflation targets, several empirical contributions suggest that the Federal Reserve has targeted a time-varying, positive inflation rate (see Cogley and Sbordone, 2008, and the references therein). As a preliminary attempt to assess the empirical relevance of our results, we calibrate the model to the US economy in order to benchmark our optimal inflation rate against Fernandez-Villaverde and Rubio-Ramirez (2008) estimates of the time-varying inflation target implicitly adopted by the Federal Reserve over the period 1957-2000. We consider different estimates of nominal rigidities found in the literature, and find that in all cases the increase in the public-transfers-to-GDP ratio observed during the high inflation sub-sample 1973-1991 causes an increase in the optimal inflation rate which accounts for a large part of the estimated increase in the Fed target in that period.

Finally, we investigate the optimal fiscal and monetary policy responses to shocks. The issue is admittedly not new, but we are able to provide new contributions to the literature. When prices are flexible and governments issue non-contingent nominal debt (Chari *et al.*, 1991) it is optimal to use inflation as a lump-sum tax on nominal wealth, and the highly volatile inflation rate allows to smooth taxes over the business cycle. This result is intuitive in so far as taxes are distortionary whereas inflation volatility is costless. SGU (2004a) show that when price adjustment is costly optimal inflation volatility is in fact minimal and long-run debt adjustment allows to obtain tax-smoothing over the business cycle. In this paper the SGU result is reversed even when the amount of public transfers is relatively small (10% of GDP). In this case tax and inflation volatility are exploited to limit debt adjustment in the long run. The interpretation of our result is simple. As discussed above, public transfers increase the tax burden in steady state. In this case, the accumulation of debt in the face of an adverse shock – which would work as a tax smoothing device in SGU (2004a) – is less desirable, because it would further increase long-run distortions. To avoid such distortions, the policymaker is induced to front-load fiscal adjustment, and to inflate away part of the real value of outstanding nominal debt.

To the best of our knowledge this is the first study of the optimal interaction between inflation and tax policies when transfers account for the relatively large proportion of public expenditures, which is documented in the data. A number of recent papers have analyzed the macroeconomic implications of public transfer schemes, but their focus is different from ours. Alonso-Ortiz and Rogerson (2010) investigate the labour supply response and the welfare implications of an optimal public transfer scheme in the context of a model with idiosyncratic productivity shocks, incomplete financial markets and flexible prices. Oh and Reis (2011) analyze the role of transfers for consumption stabilization in the context of heterogeneous agents, incomplete markets and sticky prices – when taxes are lump-sum, no public debt accumulation is allowed and the central bank is constrained to implement a zero-inflation policy. Angelopoulos *et al.* (2007) maintain the representative agent hypothesis and incorporate an uncoordinated redistributive struggle for transfers into an otherwise standard dynamic stochastic general equilibrium (DSGE) model. Zubairy (2010) investigates the consequences of temporary public transfer shocks in an estimated representative agent DSGE model.

The remainder of the paper is organized as follows. The next section introduces the model. Section 3 defines the competitive equilibrium. Section 4 illustrates our main results. Section 5 considers the consumption scale effects on the transaction costs. In section 6 we outline a calibration of our model to the US economy. Section 7 discusses optimal monetary and fiscal stabilization policies. Section 8 concludes.

2 The model

We consider a simple infinite-horizon production economy populated by a continuum of households and firms whose total measures are normalized to one. Monopolistic competition and nominal rigidities characterize both product and labor markets. A demand for money is motivated by assuming that money facilitates transactions. The government finances an exogenous stream of expenditures by levying distortionary labor income taxes and by printing money. Optimal policy is set according to a Ramsey plan.

Right from the outset, it should be noted that the focus here is on the identification of the optimal financing mix for exogenous levels of public expenditures, including both consumption and transfers. Our model therefore cannot explain government size and its composition. In this regard, our approach is identical to Klein *et al.* (2005), who investigate the optimal combination of labor, capital and corporate taxes for a given amount of total public spending.

2.1 Households

The representative household (i) maximizes the following utility function

$$U = E_{t=0} \sum_{t=0}^{\infty} \beta^t u\left(C_{t,i}, l_{t,i}\right); \; u\left(C_{t,i}, l_{t,i}\right) = \ln C_{t,i} + \eta \ln\left(1 - l_{t,i}\right) \tag{1}$$

where $\beta \in (0,1)$ is the intertemporal discount rate, $C_{t,i} = \left(\int_0^1 c_{t,i}(j)^{\rho} dj\right)^{\frac{1}{\rho}}$ is a consumption bundle, $l_{t,i}$ is a differentiated labor type that is supplied to all firms. The consumption price index is $P_t = \left(\int_0^1 p_t(i)^{\frac{\rho}{\rho-1}} di\right)^{\frac{\rho-1}{\rho}}$.

The flow budget constraint in period t is given by

$$C_{t,i}\left(1 + S_{t,i}\right) + \frac{M_{t,i}}{P_t} + \frac{B_{t,i}}{P_t} = \frac{\left(1 - \tau_t\right) w_{t,i} l_{t,i}}{P_t} + \frac{M_{t-1,i}}{P_t} + \theta_t + \frac{T_t}{P_t} + \frac{R_{t-1} B_{t-1,i}}{P_t} \tag{2}$$

where $w_{t,i}$ is the nominal wage; τ_t is the labor income tax rate; T_t denotes fiscal transfers; θ_t are firms profits; R_t is the gross nominal interest rate, $B_{t,i}$ is a nominally riskless bond that pays one unit of currency in period $t+1$. $M_{t,i}$ defines nominal money holdings to be used in period $t+1$ in order to facilitate consumption purchases.

Consumption purchases are subject to a transaction cost

$$S_{t,i} = s(v_{t,i}), \quad s'(v_{t,i}) > 0 \tag{3}$$

where $v_{t,i} = \frac{P_{t,i}C_{t,i}}{M_{t,i}}$ is the household's consumption-based money velocity. The features of $s(v_{t,i})$ are such that a satiation level of money velocity ($v^* > 0$) exists where the transaction cost vanishes and, simultaneously, a finite demand for money is associated to a zero nominal interest rate. Following SGU (2004a) the transaction cost is parameterized as

$$s(v_{t,i}) = Av_{t,i} + \frac{B}{v_{t,i}} - 2\sqrt{AB} \tag{4}$$

The first-order conditions of the household's maximization problem are:[2]

$$c_t(j) = C_t \left(\frac{p_t(j)}{P_t} \right)^{\frac{1}{\rho - 1}} \tag{5}$$

$$\lambda_t = \frac{u_c\left(C_t, l_t\right)}{1 + s(v_t) + v_t s'(v_t)} \tag{6}$$

$$\frac{\lambda_t}{\lambda_{t+1}} = \beta R_t \frac{P_t}{P_{t+1}} \tag{7}$$

$$\frac{R_t - 1}{R_t} = s'(v_t) v_t^2 \tag{8}$$

Equation (5) is the demand for the good j. As in SGU (2004a) condition (6) states that the transaction cost introduces a wedge between the marginal utility of consumption and the marginal utility of wealth that vanishes only if $v = v^*$. Equation (7) is a standard Euler condition. Equation (8) implicitly defines the household's money demand function.

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[2] When solving its optimization problem, the household takes as given goods and bond prices. As usual, we also assume that the household is subject to a solvency constraint that prevents him from engaging in Ponzi schemes.

2.2 Firms' pricing decisions

Each firm (j) produces a differentiated good using the production function:[3]

$$y_t(j) = z_t l_{t,j}, \tag{9}$$

where z_t denotes a productivity shock[4] and $l_{t,j}$ is a standard labor bundle:

$$l_{t,j} = \left[\int_0^1 l_{t,j}(i)^{\frac{\sigma-1}{\sigma}} di \right]^{\frac{\sigma}{\sigma-1}} \tag{10}$$

Firm (j) demand for labor type (i) is

$$l_{t,j}\,(i) = \left(\frac{w_{t,i}}{W_t} \right)^{-\sigma} l_{t,j} \tag{11}$$

where $W_t = \left[\int_0^1 w_{t,i}^{1-\sigma} di \right]^{\frac{1}{1-\sigma}}$ is the wage index.

We assume a sticky price specification based on Rotemberg (1982) quadratic cost of nominal price adjustment:

$$\frac{\xi_p}{2} \left(\frac{P_t(j)/P_{t-1}(j)}{\pi_{t-1}^{\delta}} - 1 \right)^2 \tag{12}$$

where $\xi_p > 0$ is a measure of price stickiness and $\pi_t = P_t/P_{t-1}$ denotes the gross inflation rate and $\delta \in [0,1]$ is the degree of price indexation to past inflation.

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[3] We abstract from capital accumulation and assume constant returns to scale of employed labor. The consequences of these two assumptions are discussed in SGU (2006) and SGU (2011) respectively. Our results are not affected by the introduction of diminishing returns to scale for labor (simulation results available upon request).

[4] We assume that $\ln z_t$ follows an $AR(1)$ process.

In a symmetrical equilibrium the price adjustment rule satisfies:

$$\frac{z_t l_t\left(\rho - mc_t\right)}{1-\rho} + \xi_p \frac{\pi_t}{\pi_{t-1}^{\delta_p}}\left(\frac{\pi_t}{\pi_{t-1}^{\delta_p}} - 1\right) = E_t \beta \frac{\lambda_{t+1}}{\lambda_t}\xi_p\left[\frac{\pi_{t+1}}{\pi_t^{\delta_p}}\left(\frac{\pi_{t+1}}{\pi_t^{\delta_p}} - 1\right)\right] \tag{13}$$

where

$$mc_t = \frac{1}{z_t}\frac{W_t}{P_t}$$

From (5) it would be straightforward to show that $\frac{1}{\rho} = \mu^p$ defines the price markup that obtains under flexible prices.

2.3 Wage-setting decisions

The labour market is also characterized by monopolistic competition and rigid nominal wages. Under flexible wages

$$\frac{W_t}{P_t} = -\mu^w \Omega_t \frac{u_l\left(C_t, l_t\right)}{u_c\left(C_t, l_t\right)} \tag{14}$$

where $\mu^w = \sigma\left(\sigma - 1\right)^{-1}$ denotes the gross wage markup and $\Omega_t = \frac{1+s(v_t)+v_t s'(v_t)}{1-\tau_t}$ denotes the policy wedge, which depends on both tax and inflation decisions.

We model nominal wage stickiness as in Rotemberg (1982). Each household maximizes the expected value of equation (1) subject to (2), (11) and to

$$\frac{\xi_w}{2}\left(\frac{W_t(i)/W_{t-1}(i)}{\pi_{t-1}^{\delta_w}} - 1\right)^2 \tag{15}$$

where $\xi_w > 0$ is a measure of wage stickiness and $\delta_w \in [0,1]$ is the degree of wage indexation to past inflation.

As a result, in a symmetrical equilibrium, the wage adjustment rule satisfies:

$$\left[(1-\tau_t)\frac{W_t}{P_t}+\frac{\mu^w u_l\left(C_t,l_t\right)\left(1+s(v_t)+v_t s'(v_t)\right)}{u_c\left(C_t,l_t\right)}\right]\frac{l_t}{\mu^w-1}+ \\ +\xi_w\left[\frac{\omega_t}{\pi_{t-1}^{\delta_w}}\left(\frac{\omega_t}{\pi_{t-1}^{\delta_w}}-1\right)\right]=E_t\beta\frac{\lambda_{t+1}}{\lambda_t}\xi_w\left[\frac{\omega_{t+1}}{\pi_t^{\delta_w}}\left(\frac{\omega_{t+1}}{\pi_t^{\delta_w}}-1\right)\right] \tag{16}$$

where $\omega_t=\frac{W_t}{W_{t-1}}$.

2.4 The government

As in SGU (2006), the government supplies an exogenous, stochastic and unproductive amount of public good G_t and implements exogenous transfers T_t.[5] Government financing is obtained through a labor-income tax, money creation and issuance of one-period, nominally risk free bonds. The government's flow budget constraint is then given by[6]

$$R_{t-1}\frac{B_{t-1}}{P_t}+G_t+T_t=\tau_t\frac{W_t}{P_t}l_t+\frac{M_t-M_{t-1}}{P_t}+\frac{B_t}{P_t} \tag{17}$$

3 The competitive equilibrium

The competitive equilibrium is a set of plans $\{C_t,l_t,\lambda_t,mc_t,\pi_t,v_t\}_{t=0}^{+\infty}$ that, given the policies $\{R_t,\tau_t\}_{t=0}^{+\infty}$, the exogenous processes $\{z_t,g_t\}_{t=0}^{+\infty}$, and the initial conditions, satisfies (6), (7), (8), (13), (16), (17) and the aggregate resource

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[5] Note that the focus of the paper is the identification of the optimal financing mix, where optimality is driven by efficiency considerations. Justifying the existence of government transfers as an optimal outcome would require some form of heterogeneity across households. This is beyond the scope of the paper.

[6] As in SGU (2004a), $\ln g_t$, $g_t=G_t/Y_t$, is assumed to evolve exogenously following an independent $AR(1)$ process. We assume instead that the level of the real transfer is non stochastic.

constraint

$$Y_t = C_t (1 + S_t) + G_t + \frac{\xi_p}{2} \left(\frac{\pi_t}{\pi_{t-1}^{\delta}} - 1 \right)^2 + \frac{\xi_w}{2} \left(\frac{w_t}{w_{t-1} \pi_{t-1}^{\delta_w}} - 1 \right)^2 \tag{18}$$

4 Ramsey policy

The Ramsey policy is a set of plans $\{R_t, \tau_t\}_{t=0}^{+\infty}$ that maximizes the expected value of (1) subject to the competitive equilibrium conditions (6), (7), (8), (13), (16), (17), (18) and the exogenous stochastic process driving the fiscal and technology shocks. Solution requires numerical simulations.[7]

4.1 The role of public expenditure variables

The first step in our analysis is to replicate the simulation exercise in SGU (2004a) with the addition that $0 < T/Y < 20\%$. Therefore, in this calibration the labour market is perfectly competitive, $\mu^w = 1$, the nominal wage is flexible, $\xi_w = 0$, and there is no indexation $\delta = \delta_w = 0$. The time unit is meant to be a year; we set the subjective discount rate β to 0.96 to be consistent with a steady-state real rate of return of 4 percent per year; transaction cost parameters A and B are set at 0.011 and 0.075; we assume the debt-to-GDP ratio is 0.44 percent; in the goods market monopolistic competition implies a gross markup of 1.2; and the annualized Rotemberg price adjustment cost is 4.375. The preference parameter η is set so that in the flexible-price steady-state households allocate 20 percent of their time to work.

Table 2

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[7] These are obtained implementing SGU (2004b) second order appoximation routines.

In Figure 1 we describe the optimal inflation response to the transfer increase and to a corresponding variation in public consumption. Simulations show that inflation rapidly increases when T/Y grows beyond the 8% threshold. For instance, the optimal inflation rate is close to 3% when T/Y is 10%, and exceeds 13% when the transfer ratio is 20%. Simulations also show that in the case where public expenditure is confined to public consumption, optimal inflation would exceed 5% only for ratio G/Y larger than 35%.[8]

Figure 1

One key mechanism driving the choice of the optimal policy mix is related to the distortionary taxation necessary to finance the additional transfers, which adversely affects the labour supply and reduces the tax base. By contrast, the increase in public consumption generates a negative wealth effect that triggers a positive labour supply response and expands the tax base. In this case the incentive to increase inflation is much reduced.

Formally, the optimal policy mix is determined by the different effects of π_t, τ_t on the policy wedge $\Omega_t = \frac{1+s(v_t)+v_t s'(v_t)}{1-\tau_t}$ in

$$\frac{W_t}{P_t} = \mu^w \Omega_t \frac{u_l\left(C_t, l_t\right)}{u_c\left(C_t, l_t\right)}$$

$\Omega_t^{'}\left(\tau_t\right)$, $\Omega_t^{'}\left(\pi_t\right) > 0$, but $\Omega_t^{''}\left(\tau_t\right) > 0$, $\Omega_t^{''}\left(\pi_t\right) = 0$. This explains why the Ramsey planner increasingly relies on the inflation tax as public expenditures grow. In Figure 2 we compare the optimal steady state value of Ω with the value that would obtain if inflation were constrained at zero.

Figure 2

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[8] Klein *et al.* (2005) calibrate their model by choosing 12% for the US and 22% for Europe).

It is interesting to compare our interpretation of the inflationary outcome generated by the need to finance transfers with the one offered by SGU (2006: 385). In fact, they claimed that when the private sector must receive an exogenous amount of (after-tax) transfers, it is optimal to exploit the inflation tax on money balances in order to impose an indirect levy on the (transfers-determined) source of household income. In our view this claim is not correct. In fact, fiscal considerations would not matter for the optimal inflation rate if lump-sum taxes were available. The incentive to choose a positive inflation rate arises because taxes are distortionary and, as shown above, financing transfers is profoundly different from financing an equivalent amount of public consumption. Thus the Ramsey planner chooses a positive inflation rate in order to limit output distortions and to increase output and consumption. In Figure 3 below we show the consumption responses to different transfer ratios when inflation is zero and when it is chosen optimally. Our interpretation of the reason why a sufficiently large amount of transfers calls for a positive inflation differs from the one presented in SGU (2006: 397), and is a novel contribution of the paper.

Figure 3

Recent studies suggest that firms adjust prices more frequently than previously thought. For instance Eichenbaum and Fischer (2007) infer that firms reoptimize prices once every 2.3–3 quarters, but cannot reject the hypothesis that firms reoptimize prices once every two quarters. In the figure below we consider the effects of different degrees of stickiness (measure as average duration of price-setting decisions) assuming that $T/Y = 10\%$. The optimal inflation rate depends on the firms' average adjustment to rest price, and substantially increase when average duration is between 2 and 3 quarters.

Figure 4

Finally, the optimal policy mix depends on monopolistic distortions. For instance, when $\mu^p = 1.1$ optimal inflation remains very close to zero for $T/Y \leq 15\%$ (Figure 5).

Figure 5

4.2 Wage stickiness.

Introducing wage stickiness has two opposite effects on the optimal inflation rate. On the one hand, monopolistic distortions raise the incentive to substitute labor taxation with the inflation tax. On the other hand, nominal wage adjustment costs strengthen the case for price stability. After setting $\mu^w = 1.2$,[9] we postulate that price and wage adjustment costs are identical ($\xi_w = \xi_p = 4.37$). Simulations show that for $T/Y < 10\%$ the two effects offset each other (Figure 6). Beyond that threshold the wage adjustment cost dominates and the optimal inflation rate falls relative to the perfect competition case.

Figure 6

4.3 Indexation

Inflation costs associated with nominal rigidities depend crucially on assumptions about the prices set by firms that cannot reoptimize. A commonly studied indexation scheme is one whereby non-reoptimized prices increase mechanically at a rate proportional to the economy-wide lagged rate of inflation (Christiano

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[9] Our choice of the wage markup follows Erceg *et al.* (2006), and is close to the value reported in Galí *et al.* (2007), but is lower than the calibration in Erceg *et al.* (2000). It should be noted, however, that Christiano *et al.* (2005, 2010) choose values much closer to one. We will consider a different calibration later.

et al., 2005). In many estimated DSGE models it is assumed that the price and wage are indexed to a weighted average of past and trend inflation, in order to obtain a vertical long-run Phillips curve (see for instance Smets and Wouters, 2005, 2007). Recent contributions provide conflicting evidence on the extent of price indexation.[10] In Figure 6 we assume an identical degree of wage and price indexation ($\delta_p = \delta_w$) ranging between 0 and 40%.[11] When $T/Y > 10\%$ even a moderate degree of indexation (20%) has a non negligible impact on optimal inflation.

Figure 7

5 Extensions: Consumption scale effects in the monetary transactions technology

The transaction cost specification adopted in (3) constrains the consumption elasticity of money demand to be one, in contrast with a large body of empirical literature.[12] Theoretical models accounting for consumption scale effects include Baumol (1952) and Khan *et al.* (2003). Attanasio *et al.* (2002) find substantial economies of scale in cash management using microdata. In a different model, Guidotti and Vegh (1993) show that the constant elasticity of scale is an unduly

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[10] Cogley and Sbordone (2008) estimate a New Keynesian Phillips Curve, finding that price indexation in the U.S. is zero once a time-varying inflation trend is accounted for. By contrast, Barnes *et al.* (2009) show that this result is not robust to the introduction of more flexible indexation schemes. Aruoba and Schorfheide (2009) find that 15% of firms optimize in each period, 60% of firms fully index their price to past inflation, the remaining firms hold their price constant. Microdata analyses suggest that indexation parameters are lower for consumption prices than for nominal wages (Du Caju *et al.* 2008; Maćkowiak and Smets, 2008). In line with this result, Fernandez-Villaverde and Rubio-Ramirez (2008) find that $\delta = 0.15$, $\delta_w = 0.85$.

[11] Introducing asymmetries in the degrees of price and wage indexation would not affect our conclusions (simulations results available upon request).

[12] See Choi and Oh (2003), Dib (2004), Knell and Stix (2005) and references therein. Christiano *et al.* (2005) obtain an estimate of 0.1.

restrictive assumption and that it is optimal to resort to the inflation tax if the transaction costs technology does not exhibit constant returns to scale. We therefore propose a definition of $S_{t,i}$ which accounts for such scale effects.

$$S_{t,i} = s(v_{t,i})g(C_{t,i})\,; \qquad g(C_{t,i}) > 0,\ g'(C_{t,i}) < 0 \tag{19}$$

where $S_{t,i}$ still vanishes at v^* and $g'(C_{t,i}) < 0$[13] allows to obtain that unit transaction costs are decreasing in consumption. We assume the following specification for the monetary transaction cost[14]

$$g(C_{t,i}) = \ C_{t,i}^{-\theta} \quad \theta \geq 0 \tag{20}$$

Note that for $\theta = 0$ scale effects in consumption expenditure vanish and (19) converges to (4)

The resulting money demand function

$$\frac{M_t}{P_t} = \frac{C_t}{\sqrt{\frac{B}{A} + (R_t - 1)\,\frac{C_t^{\theta}}{A}}} \tag{21}$$

is characterized by a consumption elasticity (η_m):

$$\eta_m = \frac{\partial\,(M_t/P_t)}{\partial C}\frac{C}{M_t/P_t} = \left[1 - \frac{1}{2}\frac{\theta\,(R-1)\,C^{\theta}}{B + (R-1)\,C^{\theta}}\right] \leq 1 \tag{22}$$

This apparently innocuous modification can have substantial implications for

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[13] We also assume that $g(C)$ is twice continuously differentiable.

[14] When $\theta = 0$ scale effects in consumption expenditure vanish and (19) converges to the transaction technology specified in SGU (2004a).

our model. In fact condition (6) now becomes

$$\lambda_t = \frac{u_c\left(C_t, l_t\right)}{1 + S_t + C_t \frac{\partial S_t}{\partial C_t}} = \frac{u_c\left(C_t, l_t\right)}{1 + \frac{s'(v_t)v_t + (1-\theta)s(v_t)}{C^{\theta}}} \tag{23}$$

The transactions-induced wedge between the marginal utility of consumption and the marginal utility of wealth unambiguously falls in θ for any level of money velocity. Our conjecture is that this should support an increase in the optimal inflation rate. To grasp intuition observe that in (14) the policy wedge Ω_t now falls in θ (as $S_{t,i}$ accounts for scale effects of transaction costs technology). This, in turn, implies that the adverse effect of inflation on the desired real wage is reduced.

We compare three different scenarios. In scenario 1 we represent an economy calibrated as in SGU (2004a), where parameters are calibrated as in Table 2 with $G/Y = 0.2$, $T/Y = 0$. In scenario 2 instead we assume sticky wages (with $\mu^p = 1.2$ and $\xi_w = 4.37$), 20% indexation on both prices and wages, public consumption set at 20% and a transfer equal to 11% of output. In scenario 3 we assume that prices are relatively flexible and the degree of price indexation to past inflation is modest, whereas wages are characterized by strong indexation, as found in Galí and Rabanal (2005), Rabanal and Rubio-Ramírez (2005), Fernandez-Villaverde and Rubio-Ramirez (2008) and Christiano *et al.* (2010). Relative to scenario 2, we set $\xi_p = 2.5$ (i.e., price are reset about every six months on average), $\delta_p = 0.15$ and $\delta_w = 0.85$.[15]

Table 3

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[15] Indexation parameters are taken from Fernandez-Villaverde and Rubio-Ramirez (2008). See below.

Our simulations (Table 3) confirm that optimal trend inflation is increasing in θ. The strongest impact on inflation is obtained in scenario 3, when price and nominal wage adjustment costs are relatively milder. In steady state equilibrium consumption scale effects have a limited, reversed hump-shaped effect on consumption elasticity of money demand, which reaches a minimum value for about $\theta = 0.6$.

6 Calibration for the US economy

In this section we calibrate the model to the US economy. Our purpose is to benchmark the optimal inflation rate against Fernandez-Villaverde and Rubio-Ramirez (2008) estimates of the time-varying inflation target implicitly adopted by the Federal Reserve over the period 1957-2000 and over the high inflation sub-sample 1973-1991.[16] The ratios G/Y and T/Y are derived from the US NIPA data. During the period 1957-2000 the average government-consumption- and transfers-to-GDP have been 20% and 9%, respectively. For the sub-sample 1973-1991 we find similar figures for G/Y and a slightly higher transfers ratio, about 10%.[17] As before we assume that the subjective discount rate β is 0.96 and the transaction cost parameters A and B are 0.011 and 0.075. For the remaining parameters (θ, ξ_p, ξ_w, δ_p, δ_w, μ^p, μ^w) we consider five alternatives (Table 4). The first calibration simply replicates the SGU (2004a) exercise augmented by public transfers. Thus, we have perfect competition in the labor market and no indexation. The second calibration differs from the first because we consider

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[16] On the relevance of inflation time-varying targets for monetary policy see Taylor (1998), Sargent (1999), Primiceri (2006), Cogley and Sbordone (2008).

[17] As shown above, beyond the 8% threshold even a modest increase in T/Y may have a strong impact the optimal inflation rate.

consumption scale effects in monetary transaction costs to the calibration. The third calibration extends the second one by introducing in the labor market monopolistic competition and nominal rigidities, which are identical to those assumed for the goods market. In addition, we allow for a moderate degree of price and wage indexation (25%). In calibration 4 the parameters describing nominal rigidities (ξ_p, ξ_w) imply that prices reoptimized on average every 10 months and wages every 9 months as in Smets and Wouters (2007). In calibration 5 we consider the highest frequency of price adjustment we found in the literature, 2 quarters, as reported in Eichenbaum and Fisher (2007).[18]

Table 4

Simulations show that for all calibrations the optimal inflation rate is positive and increasing in the sub-sample 1973-1991 (Table 5). In this regard, it is interesting to note that the optimal inflation rate is highly sensitive to the small change in T/Y observed over the two samples. A comparison between calibrations 1 and 2 highlights the role of consumption scale effects in monetary transaction costs. Differences in the price optimization inertia obviously explain differences in the optimal inflation rate. Simulation 3 and 5 seem to provide the best approximations to the estimated targets. In all cases the increase in the public-transfers-to-GDP ratio observed during the high inflation sub-sample 1973-1991 causes an increase in the optimal inflation rate which accounts for a large part of the estimated increase in the Fed target in that period.

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[18] In calibrations 4 and 5 we maintain a 25% degree of price and wage indexation because both Smets and Wouters (2007) and Eichenbaum and Fisher (2007) assume full indexation in steady state, thus obtaining a long run vertical Phillips curve. Fernandez-Villaverde and Rubio-Ramirez (2008) obtain estimates for ξ_p, ξ_w, δ_p, δ_w starting from flat priors. We do not consider here their reported values because the variant of Calvo pricing they consider imposes a constant elasticity of substitution across goods over the business cycle and overestimates the degree of price inertia. For a criticism of their approach, see Kimball (1995) and Eichenbaum and Fisher (2007).

Table 5

7 Optimal monetary and fiscal stabilization policies

In this section we investigate whether our characterization of steady-state public expenditures also bears implications for the conduct of macroeconomic policies over the business cycle. SGU (2004a) show that costly price adjustment induces the Ramsey planner to choose a minimal amount of inflation volatility and to select a permanent public debt response to shocks in order to smooth taxes over the business cycle. We compare the SGU (2004a) exercise – where ($T/Y = 0$, $G/Y = 0.2$) – with an alternative characterization of the steady state, where ($T/Y = 0.1$, $G/Y = 0.2$).[19] In Table 6 we show that when $T/Y = 0.1$ the volatility of both taxes and inflation dramatically increases whereas the strong persistence of taxes vanishes. To grasp intuition consider the impulse response functions to a 3% (one standard deviation) increase in government purchases (Figure 8). To sharpen the analysis we assume the shock is not serially correlated. Under both scenarios the permanent debt adjustment allows to smooth tax distortions. However, the different magnitudes of the permanent debt and tax adjustments associated to the two cases ($T/Y = 0$ and $T/Y = 0.1$) are also evident. When $T/Y = 0.1$, the long-run debt adjustment is reduced by 75%. In this case long-run tax distortions are already relatively large, and the accumulation of debt in the face of an adverse shock becomes less desirable. Instead,

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[19] We consider a productivity and a public consumption shocks. Parameter calibrations and properties of stochastic processes are described in Table 2. We compute the second-order approximation using SGU (2004b) routines (See also SGU 2004a: Section 7).

the planner finds it optimal to front-load tax adjustment and to inflate away part of the real value of outstanding nominal debt. This explains the surge in inflation volatility reported in Table 6. Our model is also able to match the positive empirical correlation between average inflation and inflation variability (see, e.g., Friedman, 1977; Ball and Cecchetti, 1990; Caporale and McKiernan, 1997).

Table 6 and Figure 8

8 Conclusions

Since Phelps we know that a positive inflation rate might mitigate the distortions induced by the need to finance government budgets. In contrast with previous research, we show that this argument is relevant given the policy mix between government consumption and transfers that we observe in OECD countries. This result holds for plausible parameterization of price and nominal wage adjustment costs. In addition, the size of monopolistic distortions, the degree of price and wage indexation, the consumption scale effect in monetary transaction costs unambiguously increase the optimal inflation rate. Unfortunately, empirical evidence on these latter variables is rather limited. In fact estimated DSGE models typically impose markup parameters, assume a vertical long-run Phillips curve and neglect monetary transaction costs.

Our calibrations show that the prediction of a positive inflation rate holds for the US, where the government size is relatively small. *A fortiori*, our reconsideration of the Phelps conjecture appears even more appropriate when considering countries in the Euro area where the welfare state plays a more important role.

In contrast with SGU (2011), who argue that central bank inflation targets are too high, our contribution shows that a 2% target might be too low, at least for countries where the burden of taxation is rather high, such as those of continental Europe. The explanation for this might be that commitment to a low inflation rate is used to discipline spending decisions, which we assume to be exogenous in our model. In fact several political economy models point out that distorted policymakers' incentives inflate public expenditures.[20] As shown in Acemoglu *et al.* (2009), the Ramsey-optimal taxation is substantially affected when taxes and public good provision are decided by a self-interested politician who cannot commit to policies. In a similar vein, further research should investigate how these two frictions, i.e. politicians' self-interest and lack of commitment, may affect the choice of the optimal inflation target.

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[20] See Tornell and Lane (1999) and Persson and Tabellini (2003, 2004).

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Tables

Table 1 – Government expenditures and revenues (1998-2008)*

	(1)	(2)	(3)		(1)	(2)	(3)
Australia	18,00	16,97	36,26	Japan	17,07	21,28	31,81
Austria	19,10	32,29	49,71	Netherlands	23,57	22,19	45,34
Belgium	22,13	27,82	49,39	New Zealand	17,97	20,89	42,01
Canada	19,49	21,56	42,08	Norway	20,76	23,54	56,63
Czech Republic	21,24	22,81	40,12	Poland	17,95	25,34	39,20
Denmark	25,84	27,88	55,96	Portugal	19,57	25,48	41,59
Finland	21,75	27,74	53,12	Slovak Republic	20,24	21,35	36,55
France	23,39	29,21	49,90	Spain	17,75	21,52	38,67
Germany	18,96	27,58	44,61	Sweden	26,67	29,03	57,21
Greece	16,52	28,32	40,19	Switzerland	11,4	23,48	34,40
Hungary	21,98	27,42	43,20	United Kingdom	19,83	22,28	40,38
Ireland	15,11	19,40	44,16	United States	15,26	20,51	33,47
Italy	19,10	28,94	45,25	Euro area	20,17	27,11	45,39

(1) public consumption; (2) other public expenditures; (3) total revenues

* ratios to GDP – Source OECD

Table 2 – Baseline calibration[1]

β	$= 0.96$	μ^p	$= 1.20$	μ^w	$= 1.00$
A	$= 0.011$	ξ_p	$= 4.37$	ξ_w	$= 0.00$
B	$= 0.075$	δ_p	$= 0.00$	δ_w	$= 0.00$

Table 3 – Consumption scale effects

	scenario 1		scenario 2		scenario 3	
θ	π	η_m	π	η_m	π	η_m
0.0	-0.15	1.000	4.43	1.000	7.87	1.000
0.4	0.00	0.959	4.63	0.962	8.26	0.962
0.8	0.12	0.956	4.80	0.963	8.55	0.963
1.2	0.19	0.967	4.92	0.974	8.95	0.974
1.6	0.23	0.978	4.98	0.984	9.13	0.984
2.0	0.25	0.987	5.00	0.991	9.22	0.991

Table 4 – The US economy calibration

Fixed parameters		Alternative calibrations					
			(1)	(2)	(3)	(4)	(5)
β	$= 0.96$	θ	0	2	2	2	2
A	$= 0.011$	ξ_p	4.37	4.37	4.37	7	2.47
B	$= 0.075$	ξ_w	0	0	4.37	9.5	4.37
		δ_p	0	0	0.25	0.25	0.25
		δ_w	0	0	0.25	0.25	0.25
		μ^p	1.2	1.2	1.2	1.2	1.2
		μ^w	1	1	1.2	1.2	1.2

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[1] In all the paper the $AR(1)$ processes driving the government spending and the technology shock are calibrated as in SGU (2004a), The serial correlation of $\ln g_t$ is set at 0.9 and the standard deviation of innovation to $\ln g_t$ is0.0302; the serial correlation of $\ln z_t$ is 0.82 and the standard deviation of innovation is 0.0229.

Table 5 – Optimal, observed and targeted inflation[2]

	US economy		scenario				
	observed*	est. target	(1)	(2)	(3)	(4)	(5)
(1) whole sample	4.4	3.2	1.4	2.7	3.4	2.0	4.0
(2) high inf. period (73-91)	6.4	5.6	2.9	3.9	4.3	2.7	5.2
(*) CPI inflation, excluding food and energy.							

Table 6[3]– Dynamic properties of the Ramsey allocation (2nd or. approx.)

	mean	st. dev.	auto. corr.	corr(x,y)	corr(x,g)	corr(x,z)
$T/Y = 0$, $G/Y = 0.2$						
τ	25.19	1.062	0.759	-0.305	0.436	-0.236
π	-0.16	0.177	0.034	-0.108	0.374	-0.275
R	3.82	0.566	0.863	-0.942	-0.044	-0.962
y	0.21	0.007	0.820	1.000	0.204	0.938
h	0.21	0.003	0.823	-0.085	0.590	-0.402
c	0.17	0.007	0.824	0.940	-0.123	0.954
$T/Y = 0.1$, $G/Y = 0.2$						
τ	42.69	2.860	-0.053	-0.110	0.284	-0.356
π	1.46	0.962	-0.054	-0.062	0.304	-0.309
R	5.50	0.489	0.775	-0.790	0.142	-0.926
y	0.17	0.005	0.823	1.000	0.408	0.884
h	0.17	0.003	0.714	-0.237	0.699	-0.651
c	0.13	0.005	0.783	0.851	-0.091	0.985

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[2] The estimated targets are computed from Fernandez-Villaverde and Rubio-Ramirez (2008). They report the targets for the whole period 3.2% and discuss that the target was 1.6% in the period between 1950-72 and in the 90'. From these information one can derive the target for the high-inflation period (1973-91). See also Figures 2.4 and 2.5 in their paper.

[3] In the table, τ, π, R, y, h and c stand for the tax rate, inflation rate, nominal interest rate, output, hours and consumption, respectively.

Figures

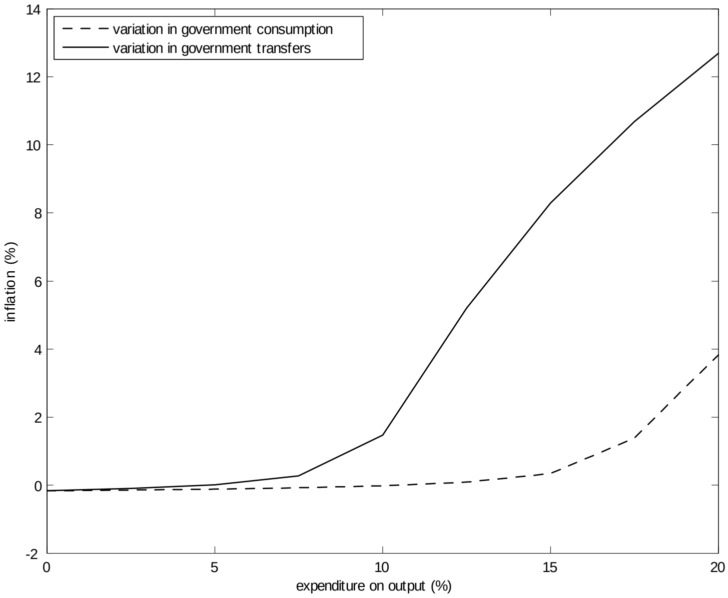

Figure 1 – Public expenditure and optimal inflation: Variation in public expenditure in addition to the 20% benchmark value for government consumption

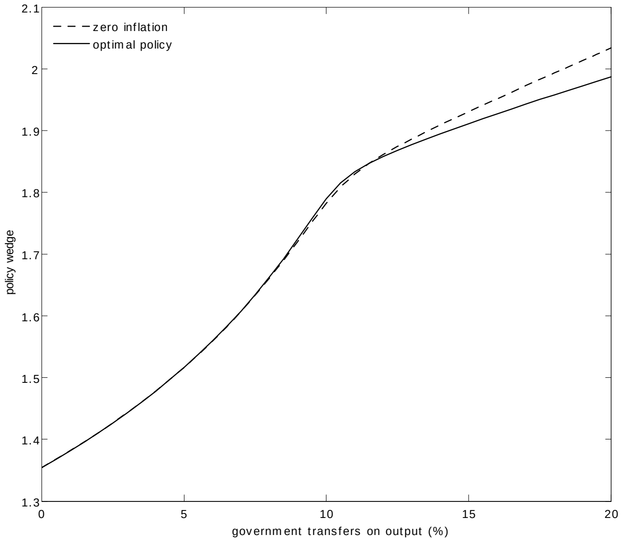

Figure 2 – Public transfers and the policy wedge

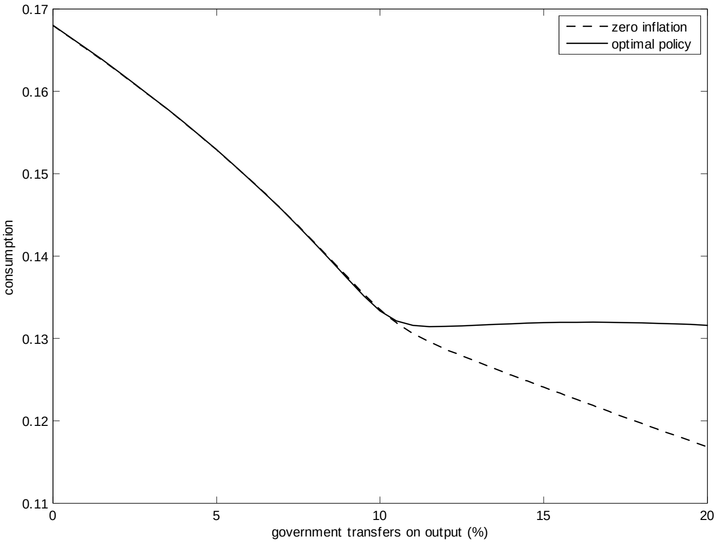

Figure 3 – Public transfers, policy wedges and consumption

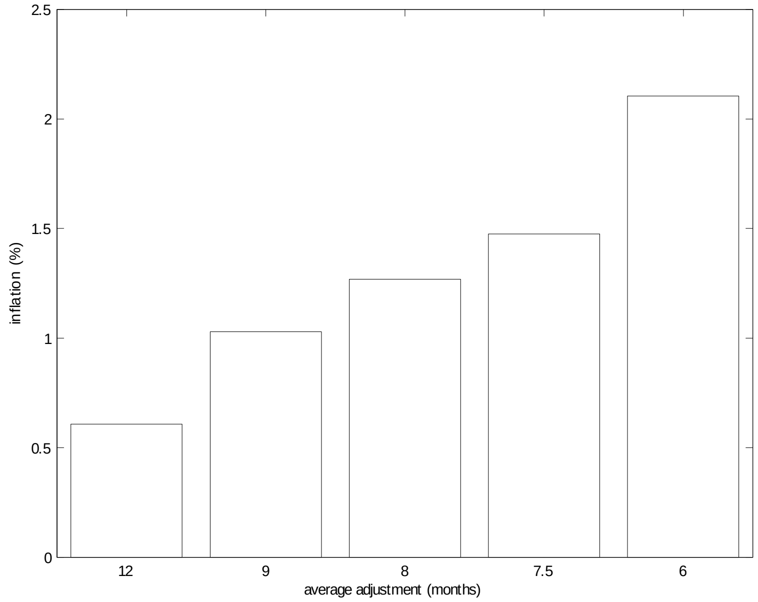

Figure 4 – Price adjustment and trend inflation

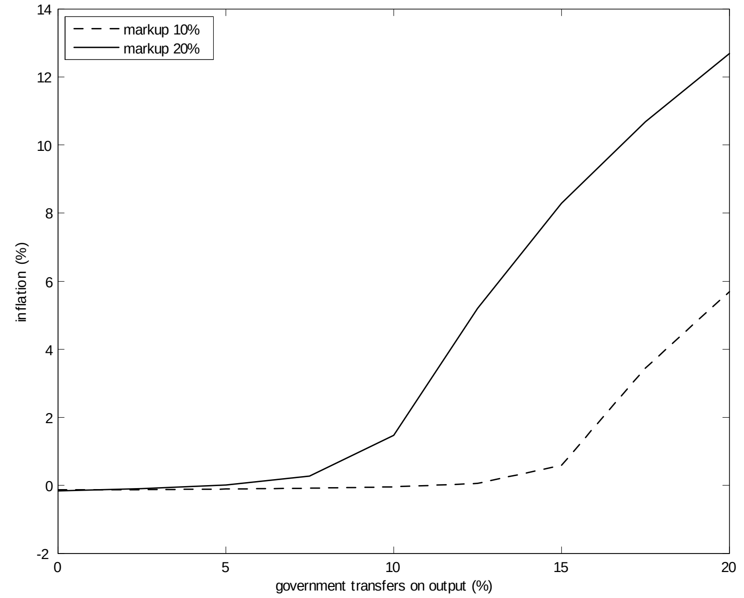

Figure 5 – Public transfers, market distortions and optimal inflation

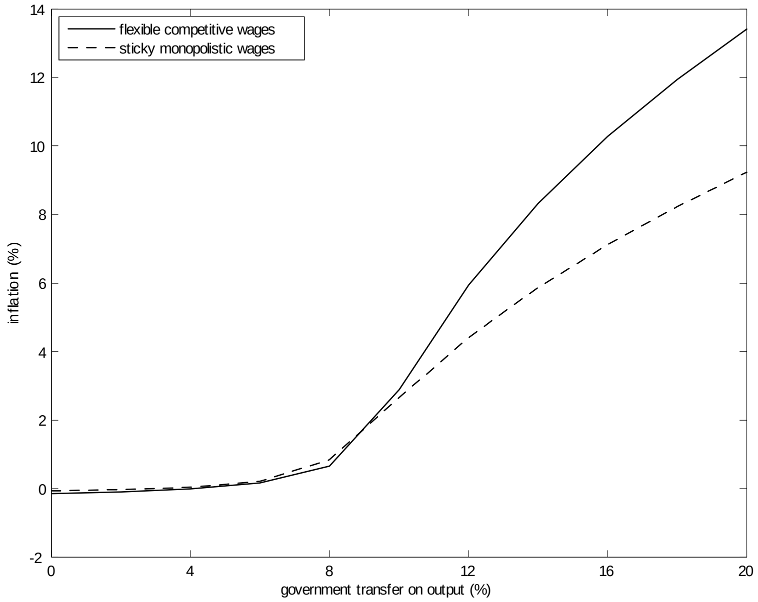

Figure 6 – Optimal inflation: Flexible vs. sticky wages

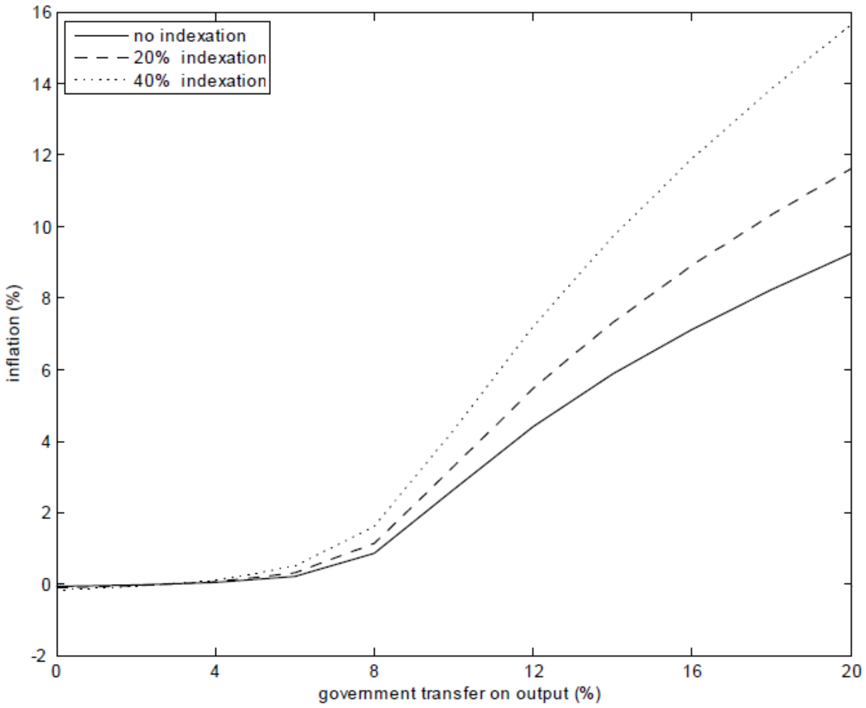

Figure 7 – Public transfers, indexation and optimal inflation

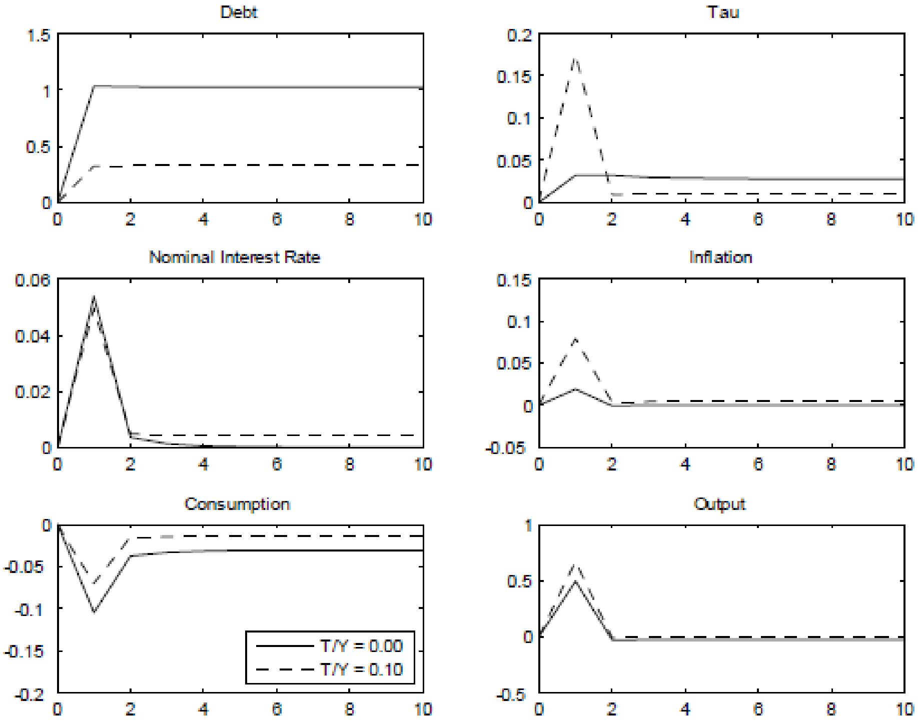

Figure 8 – Fiscal shock IRF