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**Article**

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# Efficiency of Cuts in Various Taxation Rates to Foster Economic Growth in a Framework of Wages Rigidity

*By Séverine Menguy[*]*

*We use a simple DSGE model with prices and wages rigidities to evaluate the efficiency of various fiscal policies intended to sustain economic activity and growth. We show that a fiscal policy aiming at reducing the tax burden would be all the more efficient as wages are more flexible. Besides, a decrease of the capital taxation rate appears as the most efficient fiscal policy. Indeed, it would decrease the capital cost, and it would foster private and public investment, but also private and public consumption. Wages rigidities would then reduce the inflationary tensions due to this economic growth. In comparison, a decrease of the consumption taxation rate increases private consumption, and all other components of global demand; however, economic growth is then more limited than with a decrease of the capital taxation rate. Finally, a decrease of the labor taxation rate would increase private investment and consumption and public expenditure exactly in the same proportions, but it would be much less efficient than the previous policies in order to sustain economic growth. Besides, it would favor public consumption expenditure, whereas the decrease of consumption or capital taxation rates would mainly promote the most productive public investment expenditure.*

**Keywords:** *Budgetary Policy, Capital Taxation Rate, Consumption Taxation Rate, DSGE Model, Labor Taxation Rate, Wages Rigidity.*

## Introduction

Is public expenditure growth enhancing (positive fiscal multiplier in Keynesian models), or can fiscal consolidation be expansionary? The question has been largely studied in the economic literature, without having a clear-cut answer. Indeed, these results strongly depend on the initial fiscal situation of the country: fiscal consolidations can increase private investment and economic growth, especially if the country is initially excessively indebted. They also depend on the structure of the fiscal consolidation: spending cuts (government wage bills, welfare payments, or unproductive expenditure) usually seem to be more growth-enhancing Alesina and Ardagna (2010). So, after the 1970s, the efficiency of public expenditure in order to sustain economic growth by the way of budgetary multipliers higher than one has strongly been challenged. The latter could even negative, if the public debt is excessive and if the sustainability of public finances is put into question. Besides, consolidations based on spending cuts could imply non-Keynesian effects: adjustment on the labor market and decrease in production costs could increase profits and private investment.

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More precisely, in New-Keynesian models, an increase in public expenditure increases global demand, labor demand, real wages, economic activity and private consumption. Using a DSGE model, Forni et al. (2009) underline the prevalence of empirical mild Keynesian effects of public expenditure. In particular, government purchases of goods and services, compensations for public employees or transfers to households would have small and short-lived expansionary effects on private consumption. The effects would be more significant on the revenue side: decreases in labor income and consumption tax rates would have sizeable effects on consumption and output, while a reduction in capital income taxation rate would favor investment and output in the medium run. Furthermore, Fatas and Mihov (2001) find that increases in public expenditure (particularly regarding wages of public employees) are followed by strong and persistent empirical increases in consumption and employment.

In the same way, Pappa (2004) shows that shocks to government consumption and investment increase real wages and employment contemporaneously both in US aggregate and in US state data. Indeed, a government consumption shock, financed by a higher budgetary deficit, increases global demand (absorption effect), and thus also labor demand, real wages, employment and output. Moreover, this positive effect on economic activity is the highest in case of an investment shock. Pappa (2009) also identifies fiscal shocks in the United-States, between 1969 and 2001, with a VAR methodology, using the hypothesis that fiscal shocks raise output and the budgetary deficit. Then, she shows that an increase in the public deficit as well as in public consumption or investment empirically increases real wages and employment (the evidence for public employment shocks is mixed).

On the contrary, Real Business Cycles models anticipate that increases in government spending should imply a decrease in labor productivity and in real wages; indeed, more resources are then absorbed by the government. Besides, the standard negative wealth effect implies that households feel poorer because of the decrease in their permanent income. Therefore, economic agents should increase their work effort and their labor supply, whereas they should reduce their consumption. Burnside et al. (2004) show that fiscal shocks (increase in military purchases) increase capital and labor income tax rates and aggregate hours worked, but decrease real wages. They are also associated with short lived rises in aggregate investment and small declines in private consumption. Edelberg et al. (1999) also show that an exogenous increase in US government purchases increases the present value of the tax burden for the representative household, implies a negative wealth effect, and increases labor supply. So, employment, output, the real interest rate and nonresidential investment (capital substitutable to labor in the production process) rise, while real wages, residential investment and private consumption expenditures fall.

Therefore, the question of the size and even of the sign of the budgetary multiplier is not clear cut, neither theoretically nor empirically.

To contribute to this debate, the current paper uses a DSGE model with a detailed fiscal block, in order to study the effect of the structure of public expenditures and resources. Indeed, public spending has various degrees of productivity, as some public expenditure can strongly enhance economic growth, whereas some public expenditure is quite inefficient and unproductive. Different types of public expenditure have various impacts on private factors (capital and labor) marginal productivity. Some are highly productive, in particular investment in capital: highways, airports, electric and gas facilities, water systems, etc. Some are moderately productive (education, healthcare), whereas others are quite weakly productive (entertainment, culture, national defense and environment, social transfers). Besides, regarding fiscal resources, we must also distinguish between various types of distortionary taxes: on consumption, on capital or on labor. Thanks to this detailed fiscal framework, we will then be able to shed light on the efficiency of various fiscal instruments and of variations in different taxes in order to really sustain economic growth.

The contribution of the current paper is also to introduce the stylized fact of wages rigidity on the labor market. Indeed, empirically, we can observe a high degree of wage stickiness in the economy; trade-unions have the power to avoid large wage variations and contractions. So, Christiano et al. (2005) find strong evidence in favor of sticky wages and estimate a degree of nominal wage rigidity much higher than the degree of price rigidity. The average duration of price and wage contracts in the estimated model is roughly two and three quarters, respectively, in the US between 1965 and 1995. Therefore, the authors find that wage rigidity is quantitatively at least as important as price rigidity for explaining the effects of monetary shocks and more generally, for explaining cyclical fluctuations.

Indeed, empirical wage rigidity has important implications regarding the efficiency of fiscal policies to promote economic growth. For example, Furlanetto (2007) studies the impact of a government spending shock on aggregate consumption. He shows that the model of Gali et al. (2007) implies a counterfactual increase in the real wage, the interest rate and the inflation rate. However, the introduction of sticky wages solves these problems and preserves the main result of the model, i.e. the positive response of consumption. In the context of sticky nominal wages, even without increase in the real wage, an increase in public expenditure can crowd-in and implies a positive multiplier on private consumption. Indeed, the consumption of rule of thumb consumers then increases less. However, marginal costs and inflation is also more moderate, and therefore, the interest rate increases less, and the consumption of optimizing consumers is less reduced. So, the aim of the current paper is to study the implications of a fiscal policy decreasing taxation rates on economic variables and on economic growth, but in the framework of nominal wages rigidities.

The rest of the paper is organized as follows. The second section reminds the numerous factors affecting the efficiency of the fiscal policy in order to sustain economic growth mentioned in the economic literature. The third section describes our DSGE model: economic agents, monetary and budgetary policies. The fourth, fifth and sixth sections study respectively the consequences of variations of the consumption taxation rate, of the capital taxation rate, and of the labor taxation rate. Finally, the seventh section concludes the paper.

## Economic Literature

The first parameter affecting the efficiency of an expansionary budgetary policy is the nature of the global policy-mix: the budgetary policy is all the more efficient as monetary policy is more constrained and less active. For example, Sims and Wolff (2013) study the state-dependence of the output and welfare effects of shocks to government purchases in a DSGE model with real and nominal frictions and a rich fiscal financing structure. Then, they show that the output multiplier is quite high: from 1 to 1.5, it would reach about 2 in a Zero Lower Bound (ZLB) framework (inactive monetary policy). In the same way, with a medium scale DSGE model, Zubairy (2014) estimates the effects of a discretionary fiscal policy. The multiplier for government spending would be 1.07, as higher public spending is able to boost private consumption in the short run, but its effect would be quickly decreasing in the long run. The size of this multiplier is also increased if monetary policy is more accommodative and if it is less contractionary after an increase in public expenditure. Furthermore, a cut in capital tax or labor tax of 1% would imply an increase in GDP of 0.34% and 0.13% respectively, but the stimulating effect on investment would take more time.

Davig and Leeper (2011) also underline that an increase in government purchases is all the more detrimental to economic growth as monetary policy is active. Indeed, the nominal interest rate then increases more than proportionally to inflationary expectations, and the increase in the real interest rate crowds-out private consumption. In the same way, Leeper et al. (2011) show that fiscal multipliers are larger if monetary policy is more accommodative, and in a ZLB framework where monetary policy is constrained to be more passive. They are also larger if the economy is more closed, and if the proportion of non-savers (non-Ricardian and constrained consumers) is higher. Bianchi and Ilut (2017) also interpret the policy-mix in light of the possibility of regimes changes regarding the balance of power between the monetary and fiscal authorities (whether they are active or passive, and whether a conflict of goals arises). They show that regime changes imply breaks in the persistence and volatility of inflation, as well as in the trend and accommodation of the public debt level.

Another parameter affecting the budgetary policy efficiency is the nature of the representative household, and the possibility to take into account non-Ricardian and constrained consumers. For example, Galí et al. (2007) introduce the existence of rule-of-thumb consumers in a New-Keynesian model, and they also consider sticky prices to study the effect of government spending on consumption. So, in the framework of an inter-temporal budgetary constraint of infinity-lived Ricardian households, if the budgetary deficit must later be financed, public spending crowds-out private consumption. On the contrary, in the framework of non-Ricardian households constrained to consume their current income, the budgetary multiplier can be higher than one. Besides, the authors mention that empirical evidence according to quarterly US data over the period 1954-2003 would mainly support this hypothesis (multiplier around 1.74 at the end of the second year). Therefore, the authors underline the necessity to take into account this existence of non-Ricardian consumers, in order to reconcile the theoretical results with the empirically observed expansionary consequences of higher public expenditure.

Drautzberg and Uhlig (2011) or Forni et al. (2009) also find that the fraction of transfers given to rule-of-thumb consumers improves the efficiency of an increase in public expenditure to sustain economic activity. However, Coenen and Straub (2005) revisit the effects of government spending shocks on private consumption within an estimated New-Keynesian DSGE model of the euro area. They show that the presence of non-Ricardian households (consuming current income and liquidity constrained) is in general conducive to raising the level of consumption in response to government spending shocks. Nevertheless, the latter would usually not crowd-in private consumption, because the estimated share of non-Ricardian households is relatively low, and because the highly persistent nature of government spending shocks induces large negative wealth effects, inducing households to work more but to consume less.

Another important parameter is the nature of the expansionary budgetary policy conducted by the government. Indeed, cuts in taxation rates are often found to be more expansionary than increases in public expenditure. Alesina and Ardagna (2010) examine the evidence on episodes of large stances in fiscal policy (politically motivated modification in the budgetary deficit), both in cases of fiscal stimuli (to increase GDP) and in cases of fiscal adjustments (to reduce the public debt-to-GDP ratio) in OECD countries from 1970 to 2007. They find that fiscal stimuli based upon tax cuts are more likely to increase growth than those based upon spending increases. In the same way, Ardagna (2004) uses data from a panel of OECD countries, and shows that a fiscal adjustment is more or less expansionary according to its composition. In particular, stabilizations implemented by cutting public spending would imply higher GDP growth rates.

Coenen et al. (2008) use the ECB’s New Area-Wide Model to model fiscal consolidation as a permanent reduction in the targeted government debt-to-output ratio. Then, they find that fiscal consolidation has positive long-run effects on key macroeconomic aggregates such as output and consumption, but that it gives rise to noticeable short-run adjustment costs. Mertens and Ravn (2011) also show that, in the framework of a DSGE model, ‘anticipated’ tax cuts may be contractionary. However, after their implementation, ‘surprise’ and effective exogenous tax cuts have expansionary and persistent effects on output, consumption, investment and hours worked. In the same way, according to Ludvigson (1996), deficit financed cuts in distortionary income taxation may stimulate investment and be expansionary, even if agents expect future taxes on capital income to be higher. Indeed, the fiscal shock implies a substitution from leisure to labor increasing output. Besides, higher future capital taxes decrease the returns on sparing and increase consumption levels. Furthermore, Blanchard and Perotti (2002) characterize the dynamic effects of shocks in government spending and taxes on economic activity in the United States between 1947 and 1997, using a mixed structural VAR/event study approach. They show that positive government spending shocks have a positive effect on output, and positive tax shocks have a negative effect, even if the multipliers are moderate, often close to one. Nevertheless, both increases in taxes and in government spending have a strong negative effect on investment spending, which underlines the benefits of a tax consolidation policy.

For G7 economies (excluding Italy) between the 1970's and 2010, Baum et al. (2012) show that fiscal multipliers differ across countries. Besides, the position in the business cycle affects the impact of fiscal policy on output: on average, government spending, and revenue multipliers tend to be larger in downturns than in expansions. Indeed, under a negative output gap, excess capacities are available in the economy, making the crowding out of private investment lower. Moreover, revenue multipliers would be smaller than spending multipliers; they would be particularly small in the United-States and in the United-Kingdom, whereas their impact would be statistically significant for Canada, France, Germany, and Japan. Stähler and Thomas (2012) use a DSGE model with a two-country monetary union structure, calibrated for Spain and the rest of the monetary union. They find that, in terms of output and employment losses, fiscal consolidation is the least damaging when achieved by reducing the public sector wage bill, whereas it is most damaging when carried out by cutting public investment. Besides, an increase in indirect taxation (the consumption tax rate: the VAT) to finance public expenditure, compensated by a decrease in social security contributions and in direct taxation, would be beneficial in terms of output and employment.

Finally, in the framework of a DSGE model, Bhattarai and Trzeciakiewicz (2017) show that in the United-Kingdom, between 1987 and 2010, the most stimulating fiscal policy instrument is the consumption tax cut in the short term, the capital tax cut in the medium term, and the government investment expenditure in the long term. Nevertheless, the implications of fiscal policy depend significantly on the size of nominal and real frictions. In particular, higher levels of price rigidity increase government expenditure multipliers and tax multipliers. In addition, higher nominal wage rigidity tends to decrease tax multipliers in the long term.

## The Model

In the framework of this abundant economic literature, the current paper aims at shedding light on the consequences of various fiscal policies in order to sustain economic growth. We consider a standard DSGE model, with a representative household and a representative firm. Regarding the budgetary authority, the contribution of the current paper is to take into account a developed fiscal block, where public consumption expenditure is distinguished from public investment expenditure, in order to study the consequences of the productivity of public spending on economic activity. Besides, we also distinguish between the use of various fiscal resources and distortionary taxes: on consumption, capital or labor, in order to affect economic activity. As previously mentioned, we also precisely model prices and wages rigidities. In the rest of the paper, all lower-case letters denote variables in logarithms and in variations from their long run equilibrium values.

*Households*

Aggregate demand results from the log-linearization of the Euler equation, which describes the representative household's expenditure decisions. In a given period (T), the representative household/consumer maximizes an inter-temporal utility function:

$$max \sum_{t=T}^{\infty} \beta^{t-T} E_T[U_t] \qquad (1)$$

Where: $E_t()$ is the rational expectation operator conditional on information available at date (t), and (β) is the time discount factor. Prices of goods, interest rates, taxation rates and wages are taken as given by the representative household.

We suppose that the utility function of a representative household is as follows:

$$U_t = \alpha_c \frac{\theta}{(\theta-1)} (C_t)^{\frac{(\theta-1)}{\theta}} + \alpha_g \frac{\theta}{(\theta-1)} (G_t)^{\frac{(\theta-1)}{\theta}} - \alpha_l \frac{1}{(1+\varphi)} L_t^{s(1+\varphi)} \qquad (2)$$

The indices ($0<\alpha_c<1$), ($0<\alpha_g<1$) and ($0<\alpha_l<1$) are the respective weights given to consumption of private goods, consumption of public goods and leisure in the utility function.

So, utility is an increasing and concave function of ($C_t$), an index of the household's consumption of all goods that are supplied; (θ) is the elasticity of intertemporal substitution. Utility is also an increasing and concave function of real public goods and services provided in the home country ($G_t$). Finally, utility is also a decreasing and convex function of the hours worked ($L_t^s$), where ($\varphi \geq 0$) is the inverse of the Frisch elasticity of labor supply, the inverse of the elasticity of the work effort with respect to the real wage.

This maximization is subject to a life time and inter-temporal nominal budget constraint, for whatever date (T) considered at which the actualization is realized. Regarding its expenditure, the representative household consumes goods (including taxes), it realizes investments in physical capital and it purchases government bonds. Capital is rented by households to firms, for which they receive a rental rate as well as profits which are all redistributed. Regarding its resources, the representative household receives labor and capital revenues (physical capital and profits), as well as gains from government bonds holding from the previous period. For simplicity, we suppose that these financial assets are only riskless one-period nominal government bonds. Besides, capital is not fully taxed, as we suppose that physical capital depreciation is exempted from taxation. So, if we suppose complete financial markets, a household flow budget constraint for each period (T) takes the form:

$$(1+\tau_{c,T})P_T C_T + P_T INV_T + B_T$$
$$= (1-\tau_{l,T})W_T L_T + (1-\tau_{k,T})R_T^k K_T + \delta\tau_{k,T}P_T K_T + P_T \Xi_T + (1+i_{T-1})B_{T-1} \quad (3)$$

With, in period (t): ($C_t$): real consumption; ($INV_t$): real investment in new physical capital; ($K_t$): stock of physical capital; ($P_t$): level of consumer prices; ($W_t$): nominal hourly wage; ($\tau_{l,t}$): taxation rate on labor income; ($\tau_{c,t}$): taxation rate on consumption; ($\tau_{k,t}$): taxation rate on capital; ($R_t^k$): nominal rental rate for capital services rented out to firms; ($\delta$): depreciation rate of physical capital; ($L_t$): hours worked by the household; ($i_t$): nominal interest rate; ($B_t$): nominal value of riskless one period bonds (portfolio of all claims on the government) at the end of period (t); ($\Xi_t$) Nominal profits distributed to households by firms (dividends).

Furthermore, the capital stock varies according to the following equation:

$$K_{t+1} = (1-\delta)K_t + INV_t \quad (4)$$

So, in logarithms and in terms of variations, the capital stock adjusts according to the following equation:

$$k_{t+1} = (1-\delta)k_t + \left(\frac{INV}{K}\right)inv_t = (1-\delta)k_t + \delta inv_t \quad (5)$$

Besides, the value of the real interest rate on capital is:

$$\left(\frac{R_t^k}{P_t}\right) = \left(\frac{1-\beta}{\beta}\right)\frac{1}{(1-\tau_{k,t})} + \delta \quad (6)$$

which implies: $(r_t^k - p_t) = -log(1-\widehat{\tau_{k,t}}) \sim \widehat{\tau_{k,t}} \quad (7)$

in logarithms and in variations, where a circumflex denotes a variation in the taxation rate.

In this context, the result of the maximization of equation (1) under the constraint (3) implies the following first order Euler condition, regarding timing of expenditure decisions and inter-temporal substitution, for whatever period (T):

$$\frac{1}{(1+\tau_{c,T})P_T}\frac{\partial U_T}{\partial C_T} = \frac{\beta(1+i_T)}{(1+\tau_{c,T+1})P_{T+1}}\frac{\partial E_T(U_{T+1})}{\partial C_{T+1}} \quad (8)$$

Furthermore, by combining equations (2) and (8), (∀T), we have:

$$C_T = \left[\frac{(1+\tau_{c,T+1})E_T(P_{T+1})}{\beta(1+\tau_{c,T})(1+i_T)P_T}\right]^{\theta} E_T(C_{T+1}) \quad (9)$$

So, in logarithms and in variations from their long run equilibrium values, with: log(1+x)~x provided (x) is sufficiently small; with $[\pi_t = \frac{P_t - P_{t-1}}{P_{t-1}} \sim p_t - p_{t-1}]$: inflation rate; we have:

$$c_T = E_T(c_{T+1}) - \theta[i_T - E_T(\pi_{T+1})] - \theta|\widehat{\tau_{c,T}} - E_T(\widehat{\tau_{c,T+1}})] \qquad (10)$$

Besides, for the representative agent in the country (i), we obtain the following optimal substitution between private consumption, public consumption and working time[1]:

$$\frac{\partial U_T}{\partial C_T} = -\frac{(1+\tau_{c,T})P_T}{W_T(1-\tau_{l,T})}\frac{\partial U_T}{\partial L_T^s} = \tau_{c,T}\frac{\partial U_T}{\partial G_T} \qquad (11)$$

Therefore, a higher real wage net of taxes reduces the marginal utility of leisure and increases the one of labor.

Besides, regarding labor supply, according to equations (2) and (11), in logarithms and in variations from their long run equilibrium values, we obtain[2]:

$$l_T^S = \frac{1}{\varphi}(w_T - p_T) - \frac{1}{\varphi}(\widehat{\tau_{l,T}} + \widehat{\tau_{c,T}}) - \frac{1}{\varphi\theta}c_T \qquad (12)$$

So, labor supply increases with the real wage, but it decreases with taxation rates ($\tau_{l,t}$ and $\tau_{c,t}$) reducing the purchasing power and with the disutility of working time ($\varphi$).

Besides, regarding the variation in consumption, according to equations (2) and (11), in logarithms and in variations from their long run equilibrium values, we obtain[3]:

$$g_T = c_T + \theta\widehat{\tau_{c,T}} \qquad (13)$$

Therefore, private consumption increases less than global public expenditure and the budgetary multiplier is smaller than one if the consumption taxation rate increases. However, the rest of the paper will allow distinguishing between the various components of this budgetary expenditure.

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[1]Here, we suppose that according to the budgetary constraint of the government, fiscal resources and expenditures vary in phase.

[2] $\frac{\partial U_T}{\partial L_T^s} = -\alpha_l(L_T^s)^{\varphi} = -\frac{W_T(1-\tau_{l,T})}{(1+\tau_{c,T})P_T}\frac{\partial U_T}{\partial C_T} = -\frac{W_T(1-\tau_{l,T})}{(1+\tau_{c,T})P_T}\alpha_c(C_T)^{-\frac{1}{\theta}}$.

[3] $\frac{\partial U_T}{\partial G_T} = \alpha_g(G_T)^{-\frac{1}{\theta}} = \frac{1}{\tau_{c,T}}\frac{\partial U_T}{\partial C_T} = \frac{\alpha_c}{\tau_{c,T}}(C_T)^{-\frac{1}{\theta}}$.

*Firms*

The representative firm produces a differentiated good in a monopolistic competition setting. It defines prices in order to maximize its profit, taking other variables as given. The firm rents capital and labor on perfectly competitive markets. Capital is defined according to equation (4). Wages are fixed by unions, whereas labor adjusts according to labor demand by firms. Monopolistic competition gives to goods suppliers a market power regarding price-setting, while at the same time fitting the empirical evidence of a large number of firms in the economy. So, the production function of the representative firm, including the utilization of capital and labor, has the following form:

$$Y_t = A_t K_t^{\nu} L_t^{D(1-\nu)} G_{inv,t}^{z_1} G_{c,t}^{z_2} \qquad 0 < \nu < 1 \qquad 0 < z_2 < z_1 < 1 \quad (14)$$

$$y_t = a_t + \nu k_t + (1-\nu) l_t^D + z_1 g_{inv,t} + z_2 g_{c,t} \qquad (15)$$

With ($Y_t$): real production level; ($A_t$): technology or productivity shock; ($\nu$): share of capital in the production function; ($z_1$) or ($z_2$): productivity of public expenditure.

Besides, we introduce the fact that public expenditure is made freely available by the government, and can be more ($z_1$ is high) or less ($z_2$ is small) efficient and productive in increasing the productivity of private factors. So, investment public expenditure ($G_{inv,t}$) is supposed to be more productive than consumption public spending ($G_{c,t}$), which implies ($z_1 > z_2$), whereas: ($G_t = G_{inv,t} + G_{c,t}$).

The firm maximizes its nominal profit: $\Xi_t = P_t Y_t - W_t L_t^D - R_t^k K_t$. So, this implies[1]:

$$\frac{R_t^k K_t}{W_t L_t^D} = \frac{\nu}{(1-\nu)} \qquad (16)$$

The capital-labor ratio is thus defined by the returns in the production function. So, in logarithms and in variations, we have:

$$k_t - l_t^D + r_t^k - w_t = 0 \qquad (17)$$

Let's consider a Calvo-type framework of staggered priced, where a fraction ($0<\alpha<1$) of goods prices remain unchanged each period, whereas prices are adjusted for the remaining fraction ($1-\alpha$) of goods. Monopolistically competitive firms choose their nominal prices to maximize profits subject to constraints on the frequency of future price adjustments, taking into account that prices may be fixed for many periods. So, they minimize the loss function:

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[1] $\frac{\partial \Xi_t}{\partial K_t} = \nu P_t A_t K_t^{\nu-1} (L_t^D)^{1-\nu} G_{inv,t}^{z_1} G_{c,t}^{z_2} - R_t^k = 0;$ $\quad \frac{\partial \Xi_t}{\partial L_t^D} = (1-\nu) P_t A_t K_t^{\nu} (L_t^D)^{-\nu} G_{inv,t}^{z_1} G_{c,t}^{z_2} - W_t = 0.$

$$Min_{p_t^r} \sum_{k=0}^{\infty} (\alpha\beta)^k E_t(p_t^r - \widetilde{p_{t+k}^r})^2 \qquad (18)$$

Where ($\widetilde{p_t^r}$) is the logarithm of the optimal price that the representative firm will set in period (t) if there were no price rigidity.

Thus, by deriving in function of the reset price ($p_t^r$), we have:

$$p_t^r = (1-\alpha\beta) \sum_{k=0}^{\infty} (\alpha\beta)^k E_t(\widetilde{p_{t+k}^r}) \qquad (19)$$

Therefore, the representative firm sets the optimal reset price ($p_t^r$) to the level of a weighted average of the prices that it would have expected to reset in the future if there weren't any price rigidities.

The optimal strategy of the firm is to fix prices at marginal costs: ($\widetilde{p_t^r} = mc_t$), where ($mc_t$) is the nominal marginal production cost of the representative firm. Furthermore, prices in period (t) are an average of past prices and reset prices:

$$p_t = \alpha p_{t-1} + (1-\alpha) p_t^r \qquad (20)$$

So, by combining equations (19) and (20), we obtain:

$$p_t^r = \frac{\alpha\beta}{(1-\alpha)} E_t(p_{t+1}) - \frac{\alpha^2\beta}{(1-\alpha)} p_t + (1-\alpha\beta) mc_t \quad (21)$$

Therefore, we have the following inflation rate:

$$\pi_t = \beta E_t(\pi_{t+1}) + \frac{(1-\alpha)(1-\alpha\beta)}{\alpha}(mc_t - p_t) \quad (22)$$

Inflation depends on expected future inflation, and on the gap between the frictionless optimal price level and the current price level, i.e.: on the real marginal cost. Indeed, inflationary pressures can be due to the fact that prices which can be reset by firms are increased.

Let's now clarify the expression of the real marginal production cost for the representative firm. According to equation (14), the production costs of the quantity ($Y_t$) are:

$$W_t L_t = W_t \left(\frac{Y_t}{A_t K_t^{\nu} G_{inv,t}^{z_1} G_{c,t}^{z_2}}\right)^{\frac{1}{1-\nu}} \text{ and } R_t^k K_t = R_t^k \left(\frac{Y_t}{A_t L_t^{1-\nu} G_{inv,t}^{z_1} G_{c,t}^{z_2}}\right)^{\frac{1}{\nu}} \qquad (23)$$

So, differentiating these expressions, and using equations (14) and (16), the nominal marginal production cost of the quantity ($Y_t$) is:

$$MC_t = \frac{\partial(W_t L_t)}{\partial Y_t} = \frac{\partial(R_t^k K_t)}{\partial Y_t} = \frac{(R_t^k)^\nu W_t^{1-\nu}}{\nu^\nu(1-\nu)^{1-\nu} A_t G_{inv,t}^{z_1} G_{c,t}^{z_2}} \quad (24)$$

In logarithms, we obtain the following variation in the real marginal production cost:

$$(mc_t - p_t) = (1-\nu)(w_t - p_t) + \nu\left(r_t^k - p_t\right) - (a_t + z_1 g_{inv,t} + z_2 g_{c,t}) \quad (25)$$

So, obviously, real marginal production costs increase with the real wage and with the real cost of capital services, whereas they decrease with the productivity of public expenditure. If public expenditure is more productive, inflationary tensions are less accentuated, and the monetary authority increases less the nominal interest rate, which is less detrimental to private consumption and to economic growth.

Therefore, equations (7), (12) (15), (17), (22) and (25) imply the following inflation rate, for a given period (T):

$$\pi_T = \beta E_t(\pi_{T+1}) + \frac{\varphi\mu_1(1-\nu)}{(1+\nu\varphi)} y_T + \frac{\mu_1(1-\nu)}{\theta(1+\nu\varphi)} c_T - \frac{\mu_1(1+\varphi)}{(1+\nu\varphi)}\left(a_T + z_1 g_{inv,T} + z_2 g_{c,T}\right)$$
$$+ \frac{\mu_1(1-\nu)}{(1+\nu\varphi)}\left(\widehat{\tau_{l,T}} + \widehat{\tau_{c,T}}\right) + \frac{\nu\mu_1(1+\varphi)}{(1+\nu\varphi)} \widehat{\tau_{k,T}} \quad (26)$$

$$with\colon \mu_1 = \frac{(1-\alpha)(1-\alpha\beta)}{\alpha}$$

In the same way, we can introduce some imperfection on the labor market, avoiding flexibility to fix the wage according to variations in labor demand and supply. Indeed, empirically, we can observe a high degree of wage stickiness in the economy; for example, trade-unions have a monopolistic power to avoid wage contractions. Therefore, as in Gali (2008) for example, we suppose that a fraction ($\alpha_w$) of households keep asking for the same wage, whereas the remaining fraction ($1-\alpha_w$) re-optimize the wage they desire according their competences (type of labor) and the services they provide. Indeed, households are specialized in a given labor service, monopolistically supplied, and they choose nominal wages in staggered contracts (by the way of trade unions) in order to maximize utility subject to constraints on the frequency of future wage adjustments. Besides, as in Thomas (2008) for example, we suppose that a fraction ($1-\varepsilon$) of households are able to keep their jobs between two periods, the remaining fraction ($\varepsilon$) separating from their jobs. More precisely, households minimize the loss function:

$$Min_{W_t^r} \sum_{k=0}^{\infty} [\alpha_w(1-\varepsilon)\beta]^k E_t(w_t^r - \widetilde{w_{t+k}^r})^2 \quad (27)$$

Where $(\widetilde{w_t^r})$ is the logarithm (variation) of the optimal nominal wage that the representative household will set in period (t) if there were no wage rigidity.

By analogy with the method exposed in equations (18) to (22), we have the following variation in the nominal wage ($\pi_t^w$):

$$\pi_t^w = w_t - w_{t-1} = \beta(1-\varepsilon)E_t(\pi_{t+1}^w) + \frac{(1-\alpha_w)[1-\alpha_w\beta(1-\varepsilon)]}{\alpha_w}(\widetilde{w_t^r} - w_t) \qquad (28)$$

So, equation (28) introduces a wedge between the optimal wage and the current one, leading to wage inflation, but with delays and where the adjustment is imperfect. The inflation rate in wages is accentuated if the wage reset by households and targeted for multi-period wage contracts is higher than the current one. Besides, the optimal reset wage $(\widetilde{w_t^r})$ corresponds to the marginal utility of labor in comparison with leisure. So, equations (7), (12) (15) and (17) and (28) imply the following inflation rate in nominal wages, for a period (T):

$$\pi_T^w = \beta(1-\varepsilon)E_T(\pi_{T+1}^w) + \frac{\mu_1^w}{(1-\nu)}y_T + \frac{\mu_1^w}{\theta(1+\varphi)}c_T - \frac{\mu_1^w(1+\varphi\nu)}{(1-\nu)(1+\varphi)}k_T$$
$$-\frac{\mu_1^w}{(1-\nu)}\left(a_T + z_1 g_{inv,T} + z_2 g_{c,T}\right) + \frac{\mu_1^w}{(1+\varphi)}\left(\widehat{\tau_{l,T}} + \widehat{\tau_{c,T}} - \widehat{\tau_{k,T}}\right) \qquad (29)$$

$$with{:}\ \mu_1^w = \frac{(1-\alpha_w)[1-\alpha_w\beta(1-\varepsilon)]}{\alpha_w}$$

*Global Equilibrium*

We are now going to derive the equilibrium on the goods market regarding global demand. Clearing on the goods market in period (T) requires:

$$Y_T = C_T + G_T + INV_T \qquad (30)$$

Therefore, in logarithms and in variations, we obtain:

$$y_T = \frac{C_T}{Y_T}c_T + \frac{G_T}{Y_T}g_T + \frac{INV_T}{Y_T}inv_T \qquad (31)$$

Besides, profit maximization and equations (4) and (6) imply:

$$\frac{INV_T}{Y_T} = \left(\frac{INV_T}{K_T}\right)\left(\frac{K_T}{Y_T}\right) = \delta\frac{\nu P_T}{R_T^k} = \frac{\delta\nu\beta(1-\tau_{k,T})}{[(1-\beta)+\delta\beta(1-\tau_{k,T})]} < 1 \qquad (32)$$

$$(inv_T - y_T) = -\left(r_T^k - p_T\right) = -\widehat{\tau_{k,T}} \qquad (33)$$

Let's define the output-gap as the differential between effective and potential output:

$$x_T = y_T - y_T^p \qquad (34)$$

.

By combining equations (10), (13), (30), (31), (32), (33) and (34), we obtain:

$$x_T = E_T(x_{T+1}) - \theta[i_T - E_T(\pi_{T+1}) - \bar{r_T}] \qquad (35)$$

$$\bar{r_T} = -\frac{1}{\theta}[y_T^p - E_T(y_{T+1}^p)] - \left\{1 - \frac{[(1-\beta)+\delta\beta(1-\tau_{k,T})]}{[(1-\beta)+\delta\beta(1-\nu)(1-\tau_{k,T})]}\left(\frac{G_T}{Y_T}\right)\right\}\widehat{\tau_{c,T}} - \frac{\delta\nu\beta(1-\tau_{k,T})}{\theta[(1-\beta)+\delta\beta(1-\nu)(1-\tau_{k,T})]}\widehat{\tau_{k,T}} + \frac{\delta\nu\beta(1-\tau_{k,T+1})}{\theta[(1-\beta)+\delta\beta(1-\nu)(1-\tau_{k,T+1})]}E_T(\widehat{\tau_{k,T+1}}) + \left\{1 - \frac{[(1-\beta)+\delta\beta(1-\tau_{k,T+1})]}{[(1-\beta)+\delta\beta(1-\nu)(1-\tau_{k,T+1})]}E_T\left(\frac{G_{T+1}}{Y_{T+1}}\right)\right\}E_T(\widehat{\tau_{c,T+1}}) \qquad (36)$$

- ($\theta$): real interest rate elasticity of the output-gap, 'inter-temporal elasticity of substitution' of households' expenditure.
- $\bar{r_T}$: Equilibrium or natural real interest rate, which corresponds to the steady-state real rate of return if prices and wages were fully flexible. It is the real interest rate required to keep aggregate demand equal at all times to the natural rate of output. It is a decreasing function of the temporary increase in potential output or in consumption or capital taxation rates.

So, according to equation (35), higher future expected output increases current output and consumption, because households prefer to smooth consumption, and then higher future revenues raise their current consumption and current output. Current output is also a decreasing function of the excess of the real interest rate above its natural level, because of the inter-temporal substitution of consumption.

So, we obtain the following components of global demand:

$$y_T = x_T + y_T^p \qquad (37)$$

Equation (33) implies: $inv_T = y_T - \widehat{\tau_{k,T}} = x_T + y_T^p - \widehat{\tau_{k,T}}$ (38)

Equations (10), (13), (30), (31), (32) and (33) imply:

$$c_T = g_T - \theta\widehat{\tau_{c,T}} = x_T + y_T^p - \frac{\theta[(1-\beta)+\delta\beta(1-\tau_{k,T})]}{[(1-\beta)+\delta\beta(1-\nu)(1-\tau_{k,T})]}\left(\frac{G_T}{Y_T}\right)\widehat{\tau_{c,T}} + \frac{\delta\nu\beta(1-\tau_{k,T})}{[(1-\beta)+\delta\beta(1-\nu)(1-\tau_{k,T})]}\widehat{\tau_{k,T}} \qquad (39)$$

$g_{inv,T} = x_T + y_T^p + \varepsilon_T^{g,inv}$ (40) if we note ($\varepsilon_T^{g,inv}$) the shock on public investment

$$g_{c,T} = x_T + y_T^p + \frac{\delta\nu\beta(1-\tau_{k,T})}{[(1-\beta)+\delta\beta(1-\nu)(1-\tau_{k,T})]}\left(\frac{G_T}{G_{c,T}}\right)\widehat{\tau_{k,T}}$$
$$-\frac{G_{inv,T}}{G_{c,T}}\varepsilon_T^{g,inv} + \left\{1 - \frac{[(1-\beta)+\delta\beta(1-\tau_{k,T})]}{[(1-\beta)+\delta\beta(1-\nu)(1-\tau_{k,T})]}\left(\frac{G_T}{Y_T}\right)\right\}\left(\frac{\theta G_T}{G_{c,T}}\right)\widehat{\tau_{c,T}} \quad (41)$$

Besides, potential output is the one that would prevail in absence of both price and wage rigidities. So, using equations (26), (29), (37), (39), (40) and (41), the supply functions are as follows, in differential with their long run equilibrium values:

$$\pi_T = \beta E_t(\pi_{T+1}) + \mu_1\mu_2 x_T \quad (42)$$

with: $\mu_2 = \frac{[(1+\varphi\theta)(1-\nu) - \theta(1+\varphi)(z_1+z_2)]}{\theta(1+\nu\varphi)}$

$$\pi_T^w = \beta(1-\varepsilon)E_T(\pi_{T+1}^w) + \mu_1^w\mu_2^w x_T \quad (43)$$

with: $\mu_2^w = [\frac{(1-z_1-z_2)}{(1-\nu)} + \frac{1}{\theta(1+\varphi)}]$

Equalizing the values of ($y_T^{p1}$) in equation (42) and ($y_T^{p2}$) in equation (43), we obtain a value for ($\varepsilon_T^{g,inv}$), and then also: ($y_T^p = k_T + \widehat{\tau_{k,T}}$).

*Monetary and Budgetary Policies*

The interest rate reacts to inflation and economic activity deviations according to a simple Taylor rule, but we also introduce a high degree of interest rate smoothing. So, the nominal interest rate is fixed by the central bank as follows:

$$i_T = \lambda_{i,CB}i_{T-1} + \lambda_{\pi,CB}(\pi_T - \pi^{opt}) + \lambda_{x,CB}(x_T - x^{opt}) \quad (44)$$

where ($\lambda_{i,CB}$), ($\lambda_{\pi,CB}$) and ($\lambda_{x,CB}$) are the respective weights given by the central bank to interest rate smoothing, stabilizing prices and the output-gap. Therefore, with equations (A7) and (A8) in Appendix A, we obtain:

$$i_T = f\left(i_{T-1}, \pi^{opt}, x^{opt}, \sum_{n=T+1}^{\infty} i_n, \sum_{n=T}^{\infty}\tau_{c,n}, \sum_{n=T}^{\infty}\tau_{k,n}\right) \quad (45)$$

In the framework of our model, the optimal variation in public expenditure depends on a weighted average of variations in taxation rates, on the technological progress, and on the monetary policy (nominal interest rate) conducted by the central bank. Indeed, we suppose that the public indebtedness level remains sustainable, and therefore, that the public debt level doesn't avoid to conduct the optimal budgetary policy. So, according to equations (40), (41), to the value of ($\varepsilon_T^{g,inv}$), to ($y_T^p = k_T + \widehat{\tau_{k,T}}$) and to equations (A7) and (B2) in Appendixes A and B, we obtain analytical optimal levels of public expenditure:

$$g_{inv,T} = \frac{\theta z_2 G_T}{\left(z_1 G_{c,T} - z_2 G_{inv,T}\right)(1+\theta\varphi)} \widehat{\tau_{l,T}} + f\left(a_T, (w_{T-1} - p_{T-1}), \sum_{n=T}^{\infty} i_n, \sum_{n=T}^{\infty} \widehat{\tau_{c,n}}, \sum_{n=T}^{\infty} \widehat{\tau_{k,n}}\right) \quad (46)$$

$$g_{c,T} = -\frac{\theta z_1 G_T}{\left(z_1 G_{c,T} - z_2 G_{inv,T}\right)(1+\theta\varphi)} \widehat{\tau_{l,T}} + f\left(a_T, (w_{T-1} - p_{T-1}), \sum_{n=T}^{\infty} i_n, \sum_{n=T}^{\infty} \widehat{\tau_{c,n}}, \sum_{n=T}^{\infty} \widehat{\tau_{k,n}}\right) \quad (47)$$

*Calibration*

We consider a standard calibration of the parameters of our model, in conformity with the economic literature. The preference for the present (β) is usually calibrated at (0.99), and the depreciation rate of capital is usually supposed to be (δ=0.025). The share of capital in the production function is usually estimated around (ν=0.3).

The intertemporal elasticity of substitution (θ) has a weak value of (0.5) in Leeper et al. (2011) or in Forni et al. (2009), whereas it is assumed to be (1) in Galí et al. (2007) or in papers where consumption appears in logarithm in the utility function (consistent with log preferences). In this paper, we will consider (θ=1). The calibration of the inverse of the Frisch elasticity of labor supply (φ) is very heterogeneous in the economic literature, going from (0.2) in Gali et al. (2007), until (2) in Coenen and Straub (2005) or in Drautzberg and Uhlig (2011). In this paper, we will consider (φ=1). Inertia in prices remaining unchanged is around (α=0.75) in most papers, as well as wage stickiness ($\alpha_w$=0.75).

The productivity of consumption expenditure is estimated around ($z_2$=0.05) in Sims and Wolff (2013) or in Carvalho and Martins (2011), whereas the productivity of public capital investment (highly productive) is ($z_1$=0.16) in Finn (1998) or ($z_1$=0.2) in Carvalho and Martins (2011). In this paper, we will consider ($z_1$=0.2) and ($z_2$=0.05). Thomas (2008) calibrates the proportion of workers who lose their job with the following value: (ε=0.035).

The share of private consumption in output is estimated between ($\frac{C}{Y} = 0.6$) in Smets and Wouters (2003) and ($\frac{C}{Y} = 0.63$) in Bhattarai and Trzeciakiewicz (2017). The share of private investment is estimated between ($\frac{INV}{Y} = 0.15$) in Bhattarai and Trzeciakiewicz (2017) and ($\frac{INV}{Y} = 0.22$) in Smets and Wouters (2003). The shares of public investment and consumption t are estimated between ($\frac{G_c}{Y} = 0.128$) and ($\frac{G_{inv}}{Y} = 0.032$) in the United-States in Straub and Tchakarov (2007) and ($\frac{G_c}{Y} = 0.153$) and ($\frac{G_{inv}}{Y} = 0.04$) in Drautzberg and Uhlig (2011). In this paper, we will take: ($\frac{C}{Y} = 0.64$), ($\frac{G_c}{Y} = 0.15$), ($\frac{G_{inv}}{Y} = 0.03$).

The steady–state capital income tax rate varies between ($\tau_k = 0.19$) in Forni et al. (2009) and ($\tau_k = 0.43$) in Finn (1998). The labor income tax rate varies between ($\tau_l = 0.20$) in Carvalho and Martins (2011) and ($\tau_l = 0.2844$) in Bhattarai and Trzeciakiewicz (2017). The consumption tax rate varies between ($\tau_c = 0.05$) in Drautzberg and Uhlig (2011) and ($\tau_c = 0.20$) in Bhattarai and Trzeciakiewicz (2017). In this paper, we will consider: ($\tau_k = 0.4$), ($\tau_l = 0.22$), ($\tau_c = 0.20$).

Regarding monetary policy, according to the high degree of interest rate smoothing observed in the empirical behavior of central banks, the persistence of the interest rate varies between ($\lambda_{i,CB} = 0.7$) in Leeper et al. (2011) and ($\lambda_{i,CB} = 0.92$) in Drautzberg and Uhlig (2011). The sensibility of the interest rate to the inflation rate varies between ($\lambda_{\pi,CB} = 0.13$) in Drautzberg and Uhlig (2011) and ($\lambda_{\pi,CB} = 0.45$) in Leeper et al. (2011). The sensibility of the interest rate to the output-gap varies between ($\lambda_{x,CB} = 0.01$) in Sims and Wolff (2013) and ($\lambda_{x,CB} = 0.05$) in Leeper et al. (2011). In this paper, we will consider: ($\lambda_{i,CB} = 0.8$), ($\lambda_{\pi,CB} = 0.3$) and ($\lambda_{x,CB} = 0.02$).

## Variation of the Consumption Taxation Rate

According to the economic literature (see section 2), a decrease in taxation rates could be growth enhancing, and it could improve economic activity. However, what is then the best fiscal instrument? First, the current section 4 studies the consequences of a decrease of the consumption taxation rate.

### *Consequences on Economic Activity*

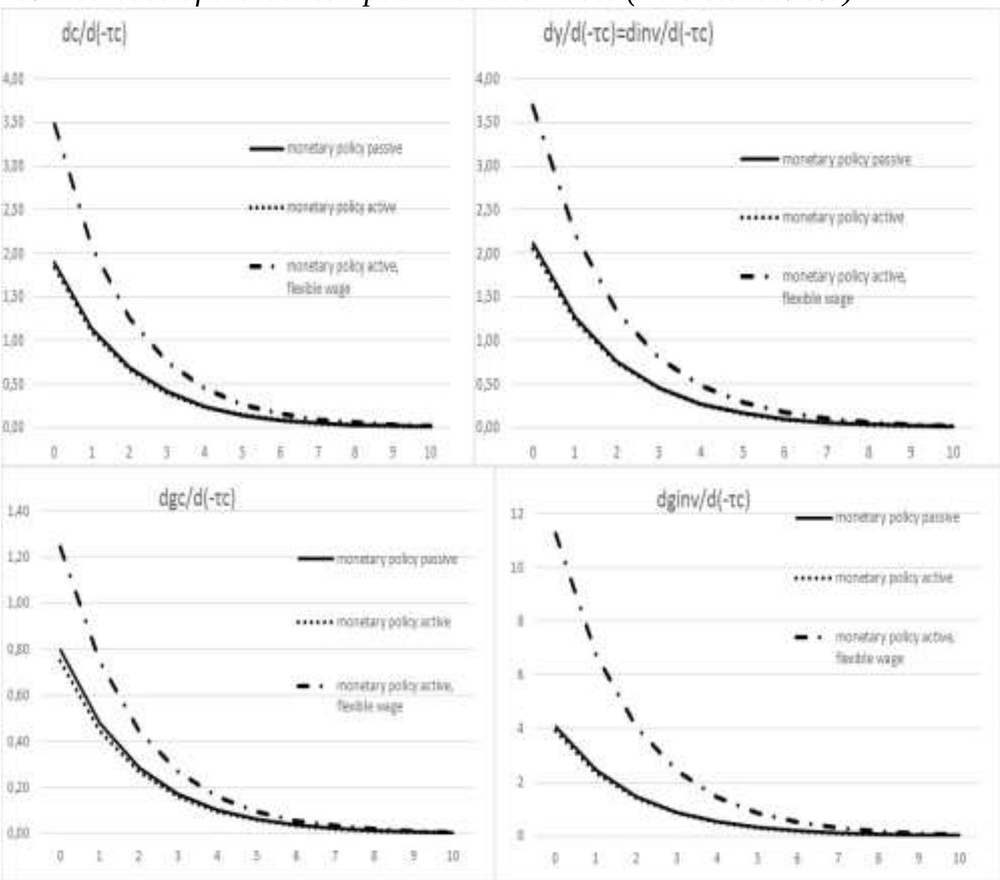
If the consumption taxation rate decreases by (-1%), according to equations (48) and (49), the expansionary effect on economic activity would be very significant: global economic activity and private investment would increase by around 2.1% in the first period, whereas private consumption would increase by around 1.9%. Indeed, as prices are reduced by the weaker consumption taxation rate, goods are less expansive, which strongly encourages private consumption and investment (see Figure 1). This economic growth could be sustained by the large increase in labor demand on the labor market (see results below).

Furthermore, according to equations (48) and (49), in a framework of flexible wages and prices ($\alpha_w \to 0$ and $\alpha \to 0$), global economic activity and private investment could increase until 3.7% in the first period, whereas private consumption would increase by 3.5%. Indeed, inflationary tensions could then contribute to sustain more strongly economic growth. More precisely, equations (45) and (B5) to (B7) in Appendix B imply:

$$\frac{\partial y_T}{\partial \widehat{\tau_{c,T}}} = \frac{\partial inv_T}{\partial \widehat{\tau_{c,T}}} = -\left\{1+\frac{[\theta(1+\nu\varphi)\mu_2+\theta(1+\varphi)+\theta(1+\varphi)(1-\nu)(\mu_1^w\mu_2^w-\mu_1\mu_2)]}{[(1-\delta)+(\mu_1\mu_2\lambda_{\pi,CB}+\lambda_{x,CB})\theta](1-\nu)}\right\} \frac{\theta}{(1+\theta\varphi)}\left\{1-\frac{[(1-\beta)+\delta\beta(1-\tau_{k,T})]}{[(1-\beta)+\delta\beta(1-\nu)(1-\tau_{k,T})]}\left(\frac{G_T}{Y_T}\right)\right\} \quad (48)$$

$$\frac{\partial c_T}{\partial \widehat{\tau_{c,T}}} = \frac{\partial y_T}{\partial \widehat{\tau_{c,T}}} - \theta\frac{[(1-\beta)+\delta\beta(1-\tau_{k,T})]}{[(1-\beta)+\delta\beta(1-\nu)(1-\tau_{k,T})]}\left(\frac{G_T}{Y_T}\right) \quad (49)$$

**Figure 1.** *Variations in Private and Public Investment and Consumption, after a 1% Decrease of the Consumption Taxation Rate (Persistence: 0.6)*



Besides, in the framework of wages rigidity, and according to equations (48) and (49), if the consumption taxation rate decreases, global economic activity, private investment and consumption are more improved if monetary policy is passive (see Figure 1). Indeed, a higher nominal interest rate (see below) would slightly reduce the expansionary consequences of the fiscal shock. More obviously, in a framework of wages flexibility, economic activity (private as well as public, investment as well as consumption expenditure) would decrease with the weight given by the central bank to the stabilization of inflation ($\lambda_{\pi,CB}$). Indeed, a higher nominal interest rate would then be necessary in order to reduce the inflationary tensions and the higher potential economic growth. Regarding the robustness of our results to a variation in the calibration of the parameters, global economic activity, private investment and consumption decrease in particular with the share of the public sector in the economy.

Another consequence of a decrease in the consumption taxation rate is to modify the composition of public expenditure [Equations (45), (46) and (47) imply analytical values for $\frac{\partial g_{inv,T}}{\partial \widehat{\tau_{c,T}}}$ *and* $\frac{\partial g_{c,T}}{\partial \widehat{\tau_{c,T}}}$]. After a decrease of (-1%) of the consumption taxation rate, global public expenditure would strongly increase, and mainly in a framework of wages flexibility. Indeed, public investment would increase by 4% in the first period (until 11.2% if wages were fully flexible), whereas public consumption expenditure would increase by 0.7% in the first period (until 1.2% if wages were fully flexible). Therefore, the decrease of the consumption taxation rate would mainly favor the most productive public investment expenditure.

*Variation in Interest Rate and in Prices*

A decrease of the consumption tax rate would increase economic activity, and would create inflationary tensions. However, in a context of wages rigidity, equation (50) shows that if the consumption tax rate decreases by (-1%), prices would only increase by (0.05%) in the first period, whereas wages would only increase by (0.11%) according to equation (51). So, in this context, the variation in nominal wages is a little bit accentuated, but wages and prices rigidities strongly reduce inflationary tensions (see Figure 2).

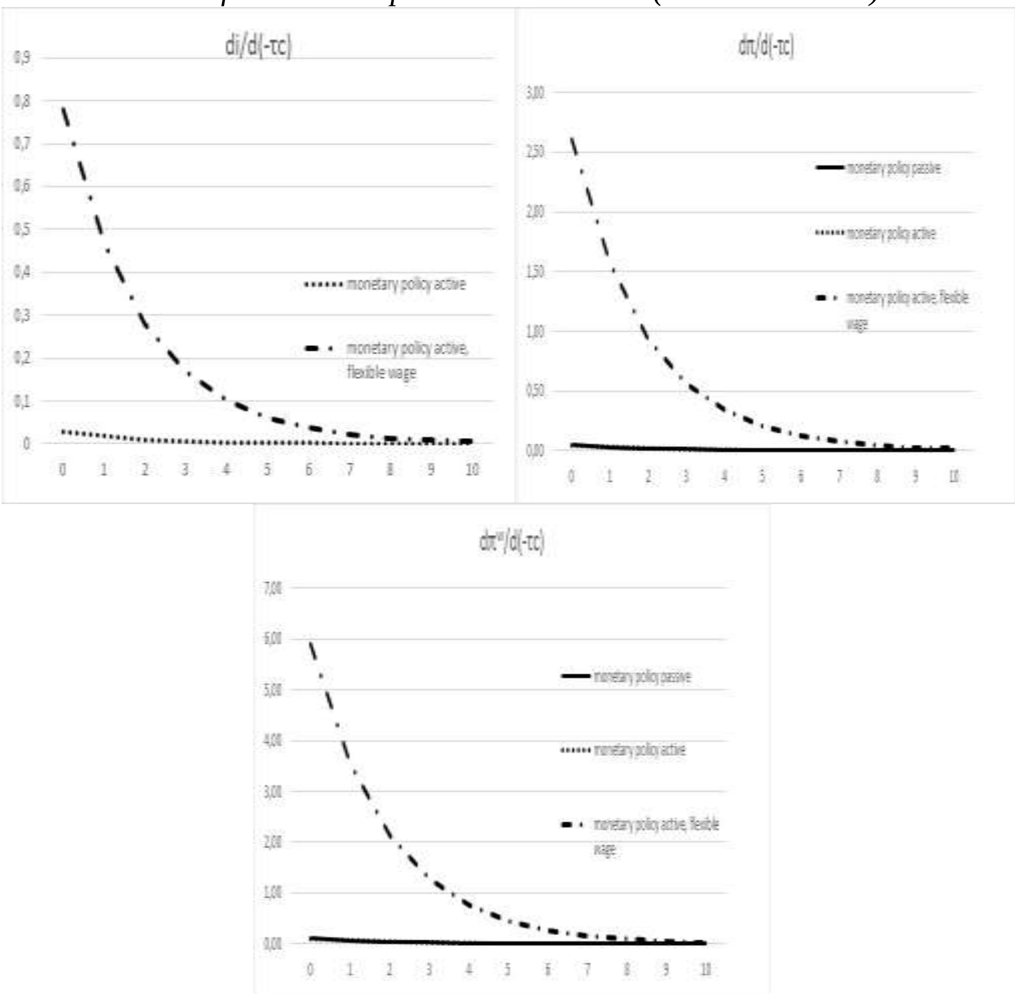
On the contrary, in a context of wages flexibility, prices could increase by (2.6%) and wages by (5.9%) in the first period, as economic growth is then much higher (see results above). Indeed, according to equations (45), (A8) and (A9) in Appendix A, we obtain:

$$\frac{\partial \pi_T}{\partial \widehat{\tau_{c,T}}} = -\frac{\theta\mu_1\mu_2}{[(1-\delta)+(\mu_1\mu_2\lambda_{\pi,CB}+\lambda_{x,CB})\theta]}\left\{1 - \frac{[(1-\beta)+\delta\beta(1-\tau_{k,T})]}{[(1-\beta)+\delta\beta(1-\nu)(1-\tau_{k,T})]}\left(\frac{G_T}{Y_T}\right)\right\} \quad (50)$$

$$\frac{\partial \pi_T^w}{\partial \widehat{\tau_{c,T}}} = \frac{\mu_1^w \mu_2^w}{\mu_1 \mu_2} \frac{\partial \pi_T}{\partial \widehat{\tau_{c,T}}} \quad (51) \qquad \frac{\partial i_T}{\partial \widehat{\tau_{c,T}}} = \frac{\left(\mu_1 \mu_2 \lambda_{\pi,CB} + \lambda_{x,CB}\right)}{\mu_1 \mu_2} \frac{\partial \pi_T}{\partial \widehat{\tau_{c,T}}} \quad (52)$$

Besides, variations in the nominal interest rate are limited, because of the hypothesis of interest rate smoothing conducted by the central bank. So, according to equation (52), after a 1% decrease of the consumption taxation rate, the nominal interest rate would only slightly increase by 0.03% in a context of wages rigidity, whereas it would increase by 0.8% if wages and prices were fully flexible, in order to reduce the inflationary tensions.

**Figure 2.** *Variations in Interest Rate, in Prices and Wages Inflation Rates after a 1% Decrease of the Consumption Taxation Rate (Persistence: 0.6)*




*The Labor Market*

The decrease of the consumption taxation rate increases the purchasing power of households as well as global demand; so, firms would increase their production levels, which necessitates a higher labor demand. As private demand strongly increases, the real wage, labor supply and demand would decrease with the share of public expenditure in the economy. Furthermore, according to equation (54), labor demand by firms would increase by around (1.2%) in the first period in a framework of wages rigidity. This increase in labor demand would strongly be accentuated if the intertemporal elasticity of substitution of households' expenditure (θ) is high, increasing the level of global demand. Indeed, according to equations (45), (B1), (B3) and (B4) in Appendix B, we obtain:

$$\frac{\partial(w_T - p_T)}{\partial\widehat{\tau_{c,T}}} = \frac{-\theta(\mu_1^w\mu_2^w - \mu_1\mu_2)}{[(1-\delta) + (\mu_1\mu_2\lambda_{\pi,CB} + \lambda_{x,CB})\theta]}\left\{1 - \frac{[(1-\beta)+\delta\beta(1-\tau_{k,T})]}{[(1-\beta)+\delta\beta(1-\nu)(1-\tau_{k,T})]}\left(\frac{G_T}{Y_T}\right)\right\} \quad (53)$$

$$\frac{\partial l_T^D}{\partial\widehat{\tau_{c,T}}} = \frac{\partial y_T}{\partial\widehat{\tau_{c,T}}} + \frac{\theta(1 + \mu_1^w\mu_2^w - \mu_1\mu_2)}{[(1-\delta) + (\mu_1\mu_2\lambda_{\pi,CB} + \lambda_{x,CB})\theta]}\left\{1 - \frac{[(1-\beta)+\delta\beta(1-\tau_{k,T})]}{[(1-\beta)+\delta\beta(1-\nu)(1-\tau_{k,T})]}\left(\frac{G_T}{Y_T}\right)\right\} \quad (54)$$

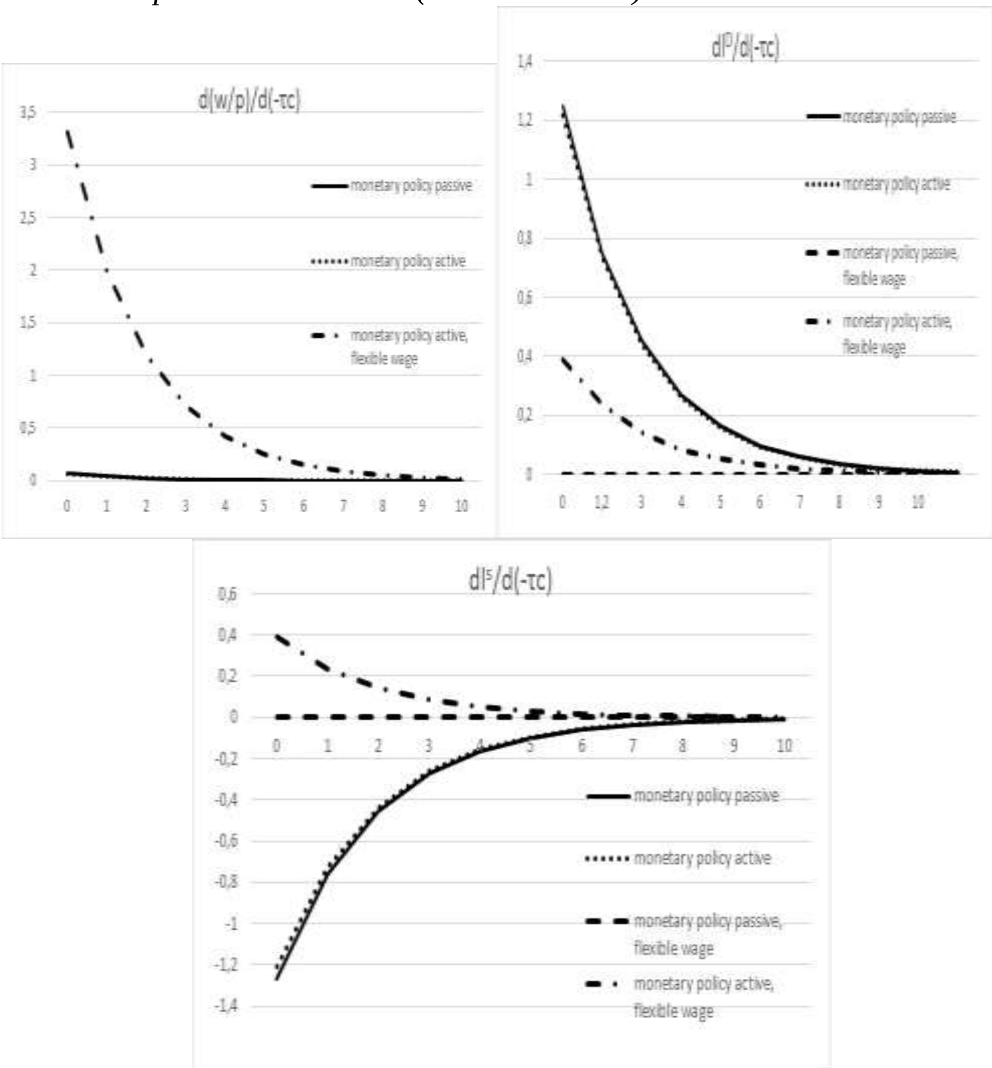
$$\frac{\partial l_T^S}{\partial\widehat{\tau_{c,T}}} = \frac{\partial y_T}{\partial\widehat{\tau_{c,T}}} + \frac{\theta[1 + \varphi + \varphi(\mu_1^w\mu_2^w - \mu_1\mu_2)(1-\nu) + (1+\nu\varphi)\mu_2]}{\varphi(1-\nu)[(1-\delta) + (\mu_1\mu_2\lambda_{\pi,CB} + \lambda_{x,CB})\theta]}\left\{1 - \frac{[(1-\beta)+\delta\beta(1-\tau_{k,T})]}{[(1-\beta)+\delta\beta(1-\nu)(1-\tau_{k,T})]}\left(\frac{G_T}{Y_T}\right)\right\}\widehat{\tau_{c,T}} \quad (55)$$

According to equation (53), this higher labor demand would imply a moderate increase of the real wage, by about (0.07%) in the first period (see Figure 3). Furthermore, the purchasing power of households would be improved by the decrease in prices; so, after a (-1%) decrease of the consumption tax rate, labor supply could decrease by around (-1.2%) [equation (55)].

On the contrary, if wages and prices were fully flexible, if the consumption taxation rate decreases by (-1%), the real wage would strongly increase, by around 3.3% in the first period according to equation (53), in order to sustain labor supply and to meet the stronger economic activity (see Figure 3). Labor supply would then increase by around 0.4%, because of the higher attractiveness of this compensation. Labor demand would then increase exactly in the same proportions, in conformity with the stronger global economic activity but also with the higher labor cost [see equation (54)].

So, a decrease of the consumption taxation rate would sustain all parameters of economic growth: private as well as public consumption and investment; besides, this economic growth would be all the more accentuated as wages are more flexible. Labor demand would increase on the labor market, in order to meet the higher global demand, which would create slight inflationary tensions and a small increase of the real wage. Nevertheless, prices and wages rigidities would then avoid the excessive increase of the real wage. They would avoid excessive inflationary tensions, which could necessitate a large increase of the nominal interest rate if wages were fully flexible.

**Figure 3.** *Labor Supply and Demand, and Real Wage after a 1% Decrease of the Consumption Taxation Rate (Persistence: 0.6)*




## Variation of the Capital Taxation Rate

### *Consequences on Economic Activity*

What could be the potential consequences of a decrease of the capital taxation rate? If the capital taxation rate decreases by (-1%), according to equation (56), the expansionary effect on economic activity would be important: global economic activity would increase by around 2.7% in the first period. Indeed, the weaker capital cost would strongly foster private investment, which would increase by around 3.7% in the first period. Private consumption and global economic activity would also increase respectively by around 2.5% and 2.7%. This economic growth could be sustained by the large increase in labor demand (see results below).

Furthermore, according to equations (56) to (58), in a framework of flexible wages and prices, global economic activity could increase until 5.3% in the first period; private investment would then increase by 6.3%, and private consumption by 5% (see Figure 4). Indeed, inflationary tensions could then contribute to sustain more strongly economic growth. More precisely, equations (45) and (B5) to (B7) in Appendix B imply:

$$\frac{\partial y_T}{\partial \widehat{\tau_{k,T}}} = -\frac{\theta\{(1+\nu\varphi)\mu_2 + (1+\varphi)[1+(1-\nu)(\mu_1^w\mu_2^w - \mu_1\mu_2)]\}[(1-\beta)+\delta\beta(1-\tau_{k,T})]}{[(1-\beta)+\delta\beta(1-\nu)(1-\tau_{k,T})][(1-\delta)+(\mu_1\mu_2\lambda_{\pi,CB}+\lambda_{x,CB})\theta](1-\nu)(1+\theta\varphi)} - \frac{\delta\beta\nu(1-\tau_{k,T})}{(1+\theta\varphi)[(1-\beta)+\delta\beta(1-\nu)(1-\tau_{k,T})]} \quad (56)$$

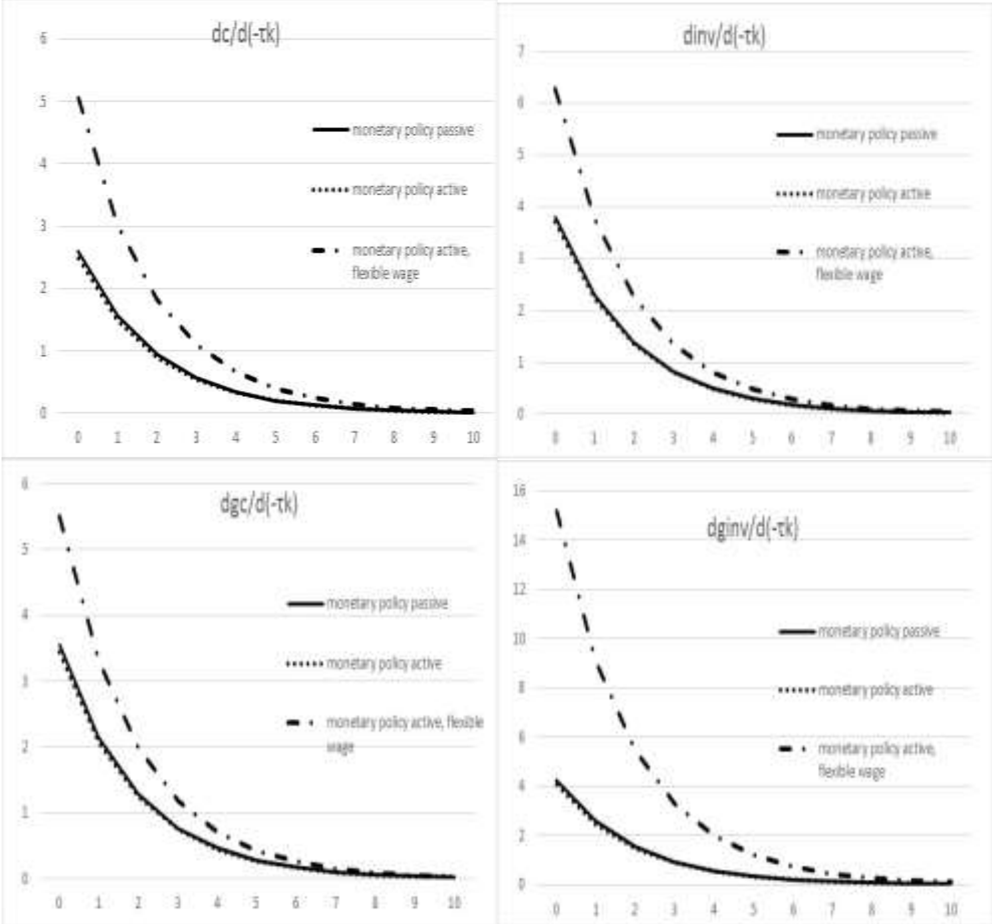
$$\frac{\partial c_T}{\partial \widehat{\tau_{k,T}}} = \frac{\partial g_T}{\partial \widehat{\tau_{k,T}}} = \frac{\partial y_T}{\partial \widehat{\tau_{k,T}}} + \frac{\delta\beta\nu(1-\tau_{k,T})}{[(1-\beta)+\delta\beta(1-\nu)(1-\tau_{k,T})]} \quad (57)$$

$$\frac{\partial inv_T}{\partial \widehat{\tau_{k,T}}} = \frac{\partial y_T}{\partial \widehat{\tau_{k,T}}} - 1 \quad (58)$$

Besides, in the framework of wages rigidity, according to equations (56) to (58), if the capital taxation rate decreases, global economic activity, private investment and consumption are more improved if monetary policy is passive. Indeed, a higher nominal interest rate (see results below) would slightly reduce the expansionary consequences of the fiscal shock. More obviously, in a framework of wages flexibility, all factors of global demand would decrease with the weight given by the central bank to the stabilization of inflation ($\lambda_{\pi,CB}$). Indeed, a higher nominal interest rate would then be necessary in order to reduce the inflationary tensions and the higher potential economic growth. Regarding the robustness of our results to a variation in the calibration of the parameters, global economic activity, private investment and consumption increase in particular with the capital share in the production function ($\nu$).

Another consequence of a decrease in the capital taxation rate is to modify the composition of public expenditure [Equations (45), (46) and (47) imply analytical values for $\frac{\partial g_{inv,T}}{\partial \widehat{\tau_{k,T}}}$ *and* $\frac{\partial g_{c,T}}{\partial \widehat{\tau_{k,T}}}$]. So, after a (-1%) decrease of the capital taxation rate, global public expenditure would strongly increase, and mainly in a framework of wages flexibility. Indeed, public investment would increase by 4% in the first period (until 15.2% if wages were fully flexible), whereas public consumption expenditure would increase by 3.4% in the first period (until 5.5% if wages were fully flexible). Therefore, the decrease of the capital taxation rate would mainly favor the most productive public investment expenditure.

**Figure 4.** *Variations in Private and Public Investment and Consumption, after a 1% Decrease of the Capital Taxation Rate (Persistence: 0.6)*




*Variation in Interest Rate and in Prices*

A decrease of the capital tax rate would increase economic activity, and would create inflationary tensions. However, in a context of wages rigidity, equation (59) shows that if the capital tax rate decreases by (-1%), prices would only increase by (0.07%) in the first period, whereas wages would only increase by (0.18%) according to equation (60). So, in this context, the variation in nominal wages is a little bit accentuated, but wages and prices rigidities strongly reduce inflationary tensions (see Figure 5).

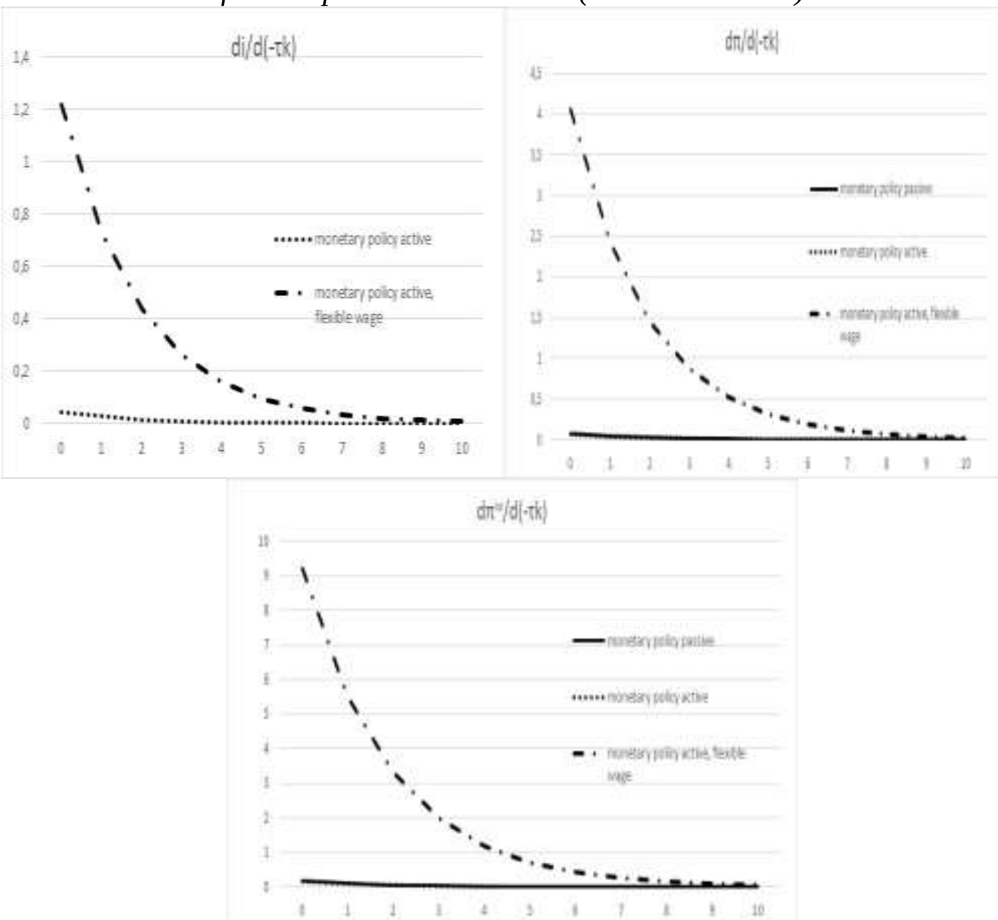
On the contrary, in a context of wages flexibility, prices could increase by (4.1%) and wages by (9.2%) in the first period, as economic growth is then much higher (see results above). Indeed, according to equations (45), (A8) and (A9) in Appendix A, we obtain:

$$\frac{\partial \pi_T}{\partial \widetilde{\tau_{k,T}}} = -\frac{\mu_1\mu_2[(1-\beta)+\delta\beta(1-\tau_{k,T})]}{[(1-\delta)+(\mu_1\mu_2\lambda_{\pi,CB}+\lambda_{x,CB})\theta][(1-\beta)+\delta\beta(1-\nu)(1-\tau_{k,T})]} \quad (59)$$

$$\frac{\partial \pi_T^w}{\partial \widehat{\tau_{k,T}}} = \frac{\mu_1^w \mu_2^w}{\mu_1 \mu_2} \frac{\partial \pi_T}{\partial \widehat{\tau_{k,T}}} \quad (60) \qquad \frac{\partial i_T}{\partial \widehat{\tau_{k,T}}} = \frac{(\mu_1 \mu_2 \lambda_{\pi,CB} + \lambda_{x,CB})}{\mu_1 \mu_2} \frac{\partial \pi_T}{\partial \widehat{\tau_{k,T}}} \quad (61)$$

Besides, variations in the nominal interest rate are limited, because of the hypothesis of interest rate smoothing conducted by the central bank. So, according to equation (61), after a 1% decrease of the capital taxation rate, the nominal interest rate would only slightly increase by 0.05% in a context of wages rigidity, whereas it would increase by 1.2% if wages and prices were fully flexible, in order to reduce the inflationary tensions.

**Figure 5.** *Variations in Interest Rate, In Prices and Wages Inflation Rates after a 1% Decrease of the Capital Taxation Rate (Persistence: 0.6)*




*The Labor Market*

The decrease of the capital taxation rate reduces the real capital cost proportionately. So, given the huge reduction in production costs, firms would increase their levels of private investment and production, which necessitates a higher labor demand. Therefore, according to equation (63), labor demand by firms would increase by around (1.4%) in the first period in a framework of wages rigidity (see Figure 6). Indeed, according to equations (45), (B1), (B3) and (B4) in Appendix B, we obtain:

$$\frac{\partial(w_T - p_T)}{\partial\widehat{\tau_{k,T}}} = -\frac{(\mu_1^w\mu_2^w - \mu_1\mu_2)\left[(1-\beta) + \delta\beta\left(1-\tau_{k,T}\right)\right]}{\left[(1-\delta) + \left(\mu_1\mu_2\lambda_{\pi,CB} + \lambda_{x,CB}\right)\theta\right]\left[(1-\beta) + \delta\beta(1-\nu)\left(1-\tau_{k,T}\right)\right]} \quad (62)$$

$$\frac{\partial l_T^D}{\partial\widehat{\tau_{k,T}}} = \frac{\partial y_T}{\partial\widehat{\tau_{k,T}}} + \frac{(1 + \mu_1^w\mu_2^w - \mu_1\mu_2)\left[(1-\beta) + \delta\beta\left(1-\tau_{k,T}\right)\right]}{\left[(1-\delta) + \left(\mu_1\mu_2\lambda_{\pi,CB} + \lambda_{x,CB}\right)\theta\right]\left[(1-\beta) + \delta\beta(1-\nu)\left(1-\tau_{k,T}\right)\right]} \quad (63)$$

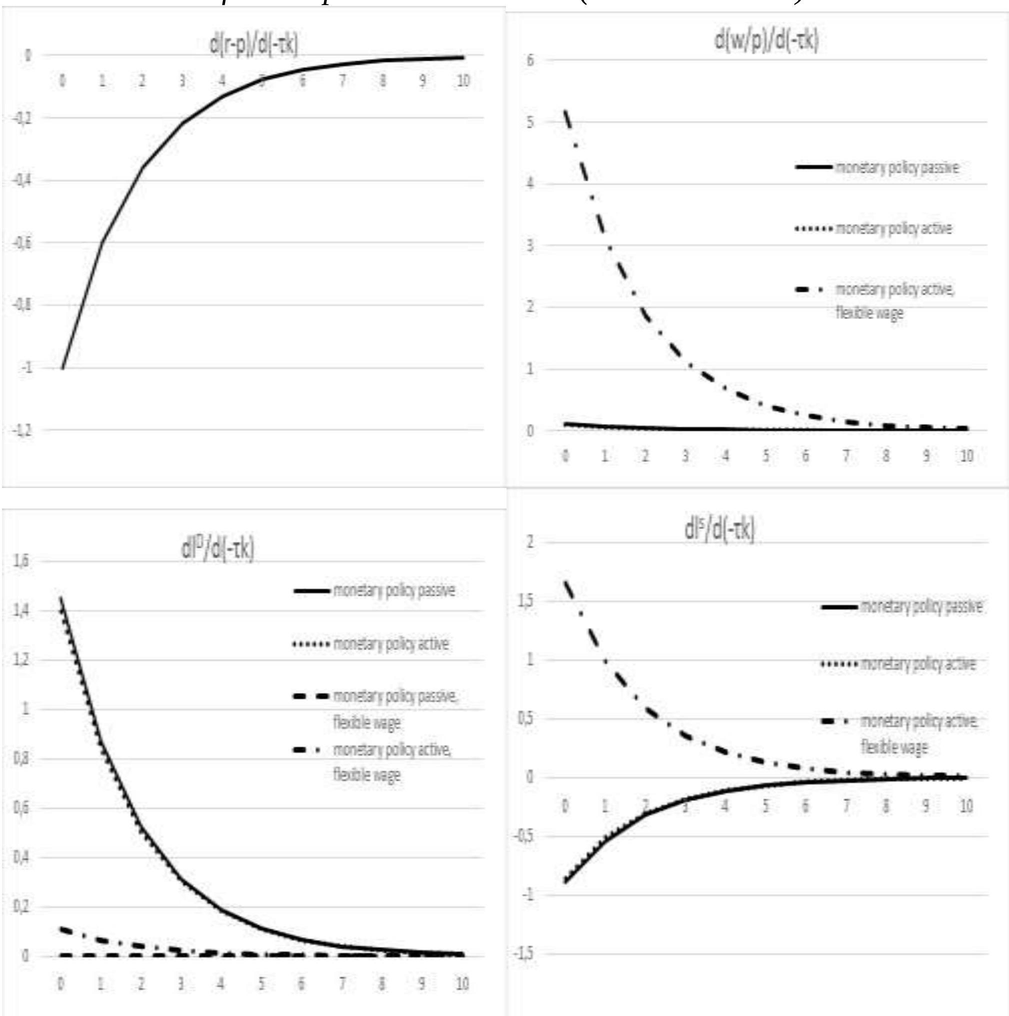
$$\frac{\partial l_T^S}{\partial\widehat{\tau_{k,T}}} = \frac{\partial y_T}{\partial\widehat{\tau_{k,T}}} + \frac{\left[(1-\beta) + \delta\beta\left(1-\tau_{k,T}\right)\right]\left[(1+\nu\varphi)\mu_2 + (1+\varphi) + \varphi(1-\nu)(\mu_1^w\mu_2^w - \mu_1\mu_2)\right]}{\varphi\left[(1-\delta) + \left(\mu_1\mu_2\lambda_{\pi,CB} + \lambda_{x,CB}\right)\theta\right]\left[(1-\beta) + \delta\beta(1-\nu)\left(1-\tau_{k,T}\right)\right](1-\nu)} \quad (64)$$

According to equation (62), this higher labor demand would imply a moderate increase of the real wage, by about (0.1%) in the first period. So, the purchasing power of households would be improved by the higher real wage, and after a (-1%) decrease of the capital tax rate, labor supply could decrease by around (-0.9%) in the first period, according to equation (64).

On the contrary, if wages and prices were fully flexible, if the capital taxation rate decreases by (-1%), the real wage would strongly increase, by around 5.1% in the first period according to equation (62), in order to sustain labor supply and to meet the stronger economic activity. Labor supply would then increase by around 1.6% in the first period, in conformity with the higher attractiveness for households of this compensation. Nevertheless, among the production factors, the weaker capital cost and higher labor cost would be harmful to labor demand, despite the growing global economic activity. According to equation (63), labor demand would then very slightly increase by around 0.1% in the first period, and only if monetary policy is active.

So, a decrease of the capital taxation rate would mainly favor private and public investment expenditure, because of the reduction of the capital cost. It would also strongly increase private and public consumption; finally, it would be slightly more efficient than a decrease of the consumption taxation rate (see section 4) in order to sustain economic growth. Besides, this economic growth (private as well as public, investment as well as consumption expenditure) would be all the more accentuated as wages are more flexible. Furthermore, labor demand would increase on the labor market, in order to meet the higher global demand, which would create slight inflationary tensions and a small increase of the real wage. Nevertheless, wages rigidity would then avoid the excessive increase of the real wage and of labor supply, which could imply a large unemployment rate if wages were fully flexible. Wages and prices rigidities would also avoid excessive inflationary tensions, which would necessitate a strong increase of the nominal interest rate if wages were fully flexible.

**Figure 6.** *Real Capital Cost, Labor Supply and Demand, and Real Wage after a 1% Decrease of the Capital Taxation Rate (Persistence: 0.6)*




## Variation OF the Labor Taxation Rate

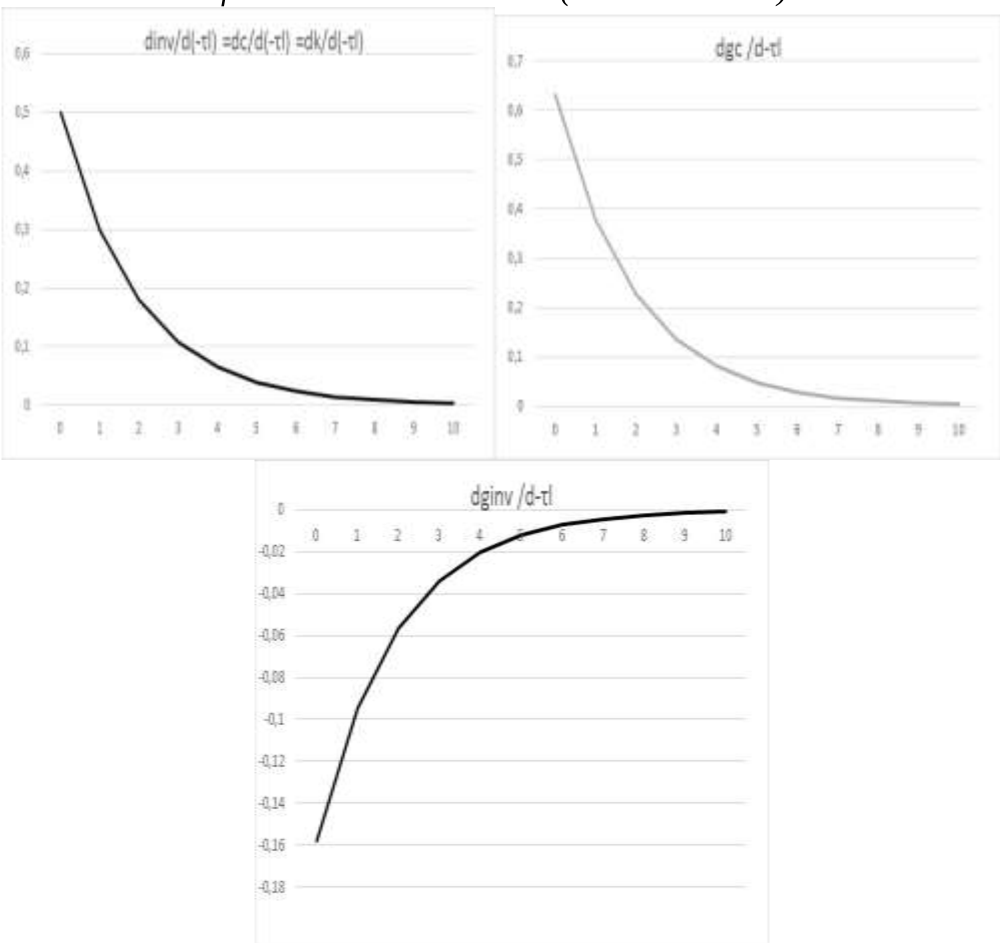
The last fiscal policy to study is a variation of the labor taxation rate. According to equations (45), (A8) and (A9) in Appendix A, a variation of the labor taxation rate implies no variation of interest rates, wages or prices inflation rates. However, it has non negligible consequences on other economic variables, which are independent from wages flexibility on the labor market and from monetary policy activism.

### *Consequences on Economic Activity*

If the labor taxation rate decreases by (-1%), according to equation (65), the expansionary effect on economic activity would be moderate: all demand factors would increase by around 0.5% in the first period. Indeed, the higher purchasing power of households (less taxes) would increase private consumption and global demand (see Figure 7). This economic growth could be sustained by the large increase of labor demand on the labor market (see results below). More precisely, equations (45), (B5) to (B7) in Appendix B imply:

$$\frac{\partial y_T}{\partial \widehat{\tau_{l,T}}} = \frac{\partial inv_T}{\partial \widehat{\tau_{l,T}}} = \frac{\partial c_T}{\partial \widehat{\tau_{l,T}}} = \frac{\partial g_T}{\partial \widehat{\tau_{l,T}}} = -\frac{\theta}{(1+\theta\varphi)} \qquad (65)$$

**Figure 7.** *Variations in Private and Public Investment and Consumption, after a 1% Decrease of the Labor Taxation Rate (Persistence: 0.6)*




Regarding the robustness of our results to a variation in the calibration of the parameters, economic activity would increase with the inter-temporal elasticity of substitution of households' expenditure (θ), and with the elasticity of labor supply (1/φ).

A decrease of the labor taxation rate also modifies the composition of public expenditure. Indeed, equations (45), (46) and (47) imply:

$$\frac{\partial g_{inv,T}}{\partial \widehat{\tau_{l,T}}} = \frac{\theta z_2 G_T}{(z_1 G_{c,T} - z_2 G_{inv,T})(1+\theta\varphi)} \quad (66) \qquad \frac{\partial g_{c,T}}{\partial \widehat{\tau_{l,T}}} = -\frac{\theta z_1 G_T}{(z_1 G_{c,T} - z_2 G_{inv,T})(1+\theta\varphi)} \quad (67)$$

So, after a (-1%) decrease of the labor taxation rate, global public expenditure would slightly increase, but public investment expenditure would decrease by (-0.16%) whereas public consumption expenditure would increase by 0.63% in the first period. Therefore, the decrease of the labor taxation rate would mainly favor the less productive public consumption expenditure.

*The Labor Market*

The decrease of the labor taxation rate implies no variation in the real wage. So, it would increase labor supply, as labor would become relatively more attractive for households. Besides, as the purchasing power of households is increased, global demand also increases, which necessitates a higher production level and a higher labor demand by firms. This higher labor demand can be satisfied without increasing wages; indeed, with weaker labor taxation rates, workers reduce their wage claims. So, according to equation (68), if the labor taxation rate decreases by (-1%), labor supply and demand would moderately increase by around (0.5%) in the first period, in the same proportions as global economic activity (see results above). According to equations (45), (B3) and (B4) in Appendix B, we obtain:

$$\frac{\partial l_T^S}{\partial \widehat{\tau_{l,T}}} = \frac{\partial l_T^D}{\partial \widehat{\tau_{l,T}}} = -\frac{\theta}{(1+\theta\varphi)} \quad (68)$$

So, a decrease of the labor taxation rate would increase private investment and consumption and public expenditure in the same proportions. The similar increase in labor supply and demand would then always allow to reach the first best equilibrium on the labor market without wage inflation. However, it would be much less efficient than a decrease in the consumption or capital taxation rates in order to sustain economic growth. Besides, such a fiscal policy would favor the less productive public consumption expenditure to the detriment of public investment expenditure.

## Conclusion

We have used a simple DSGE model with prices and wages rigidities in order to evaluate the efficiency of various fiscal policies in order to sustain economic activity and growth. Our modeling shows that a fiscal policy aiming at reducing the tax burden and taxation rates would be all the more efficient in sustaining economic growth as wages are more flexible.

Besides, a decrease of the capital taxation rate appears as the most efficient fiscal policy. Indeed, it would decrease the capital cost, and it would foster private and public investment, but also private and public consumption. Wages rigidities would then reduce the inflationary tensions due to this economic growth, even if wages inflation would then be slightly higher than prices inflation. Furthermore, if wages were fully flexible, such rigidities would also be necessary in order to avoid an out-bidding of labor supply, real wages, and of the unemployment rate on the labor market. In comparison, a decrease of the consumption taxation rate is less efficient in sustaining economic growth. As goods are less expansive, it increases private consumption, and all other components of global demand; however, economic growth is then more limited than in the context of a decrease of the capital taxation rate. Nevertheless, we can mention that the decrease of the consumption taxation rate would avoid any disequilibrium on the labor market in a framework of a very high wage flexibility. Finally, a decrease of the labor taxation rate would increase private investment and consumption and public expenditure in the same proportions, and it would allow to reach the first best on the labor market without wage inflation. However, it would be much less efficient than a decrease of the consumption or capital taxation rates in order to sustain economic growth. Besides, regarding the composition of public expenditure, such a fiscal policy would favor public consumption expenditure, whereas the decrease of consumption or capital taxation rates would mainly promote the most productive public investment expenditure.

So, this paper gives interesting indications regarding the efficiency of reductions in various taxation rates in order to sustain economic activity. Nevertheless, future researches could include the following directions. We would like to study the consequences of the introduction of rule of thumb consumers who cannot optimize their consumption level but who simply consume their disposable income, as well as transfers from the government to these agents. We could also study more specifically the monetary-fiscal policy mix effect (which authority is active or passive, which coordination is put in place). Finally, we would like to study the consequences of the introduction of an open-economy framework, where households consume both domestically produced and foreign goods, allowing a differential between producer and consumer prices.

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**Appendix A: Optimal Output-Gap, Prices and Wages Inflation Rates**

Equations (5) and (38) imply: $k_{T+1} = k_T + \delta x_T \quad (A1)$
Equations (35), (36), (A1) and ($y_T^p = k_T + \widehat{\tau_{k,T}}$) imply:

$$x_T = \frac{1}{(1-\delta)} E_T(x_{T+1}) + \frac{\theta}{(1-\delta)} E_T(\pi_{T+1}) + \frac{1}{(1-\delta)} \lambda_T \quad (A2)$$

$$\lambda_T = -\theta i_T - \theta \left\{ 1 - \frac{[(1-\beta) + \delta\beta(1-\tau_{k,T})]}{[(1-\beta) + \delta\beta(1-\nu)(1-\tau_{k,T})]} \left(\frac{G_T}{Y_T}\right) \right\} \widehat{\tau_{c,T}}$$
$$+\theta \left\{ 1 - \frac{[(1-\beta) + \delta\beta(1-\tau_{k,T+1})]}{[(1-\beta) + \delta\beta(1-\nu)(1-\tau_{k,T+1})]} E_T\left(\frac{G_{T+1}}{Y_{T+1}}\right) \right\} E_T\left(\widehat{\tau_{c,T+1}}\right)$$
$$- \frac{[(1-\beta) + \delta\beta(1-\tau_{k,T})]}{[(1-\beta) + \delta\beta(1-\nu)(1-\tau_{k,T})]} \widehat{\tau_{k,T}}$$
$$+ \frac{[(1-\beta) + \delta\beta(1-\tau_{k,T+1})]}{[(1-\beta) + \delta\beta(1-\nu)(1-\tau_{k,T+1})]} E_T(\widehat{\tau_{k,T+1}})$$

Equations (42), (43) and (A2) imply:

$$\pi_T = \left[\beta + \frac{\theta\mu_1\mu_2}{(1-\delta)}\right] E_T(\pi_{T+1}) + \frac{\mu_1\mu_2}{(1-\delta)} E_T(x_{T+1}) + \frac{\mu_1\mu_2}{(1-\delta)} \lambda_T \quad (A3)$$

$$\pi_T^w = \beta(1-\varepsilon) E_T(\pi_{T+1}^w) + \frac{\theta\mu_1^w\mu_2^w}{(1-\delta)} E_T(\pi_{T+1}) + \frac{\mu_1^w\mu_2^w}{(1-\delta)} E_T(x_{T+1})$$
$$+ \frac{\mu_1^w\mu_2^w}{(1-\delta)} \lambda_T \quad (A4)$$

So, this implies to solve the following system:

$$\begin{pmatrix} x_T \\ \pi_T \\ \pi_T^w \end{pmatrix} = A \begin{pmatrix} E_T(x_{T+1}) \\ E_T(\pi_{T+1}) \\ E_T(\pi_{T+1}^w) \end{pmatrix} + \frac{1}{(1-\delta)} \begin{pmatrix} \lambda_T \\ \mu_1\mu_2\lambda_T \\ \mu_1^w\mu_2^w\lambda_T \end{pmatrix}$$

With: $\lim_{n\to\infty} x_n = \lim_{n\to\infty} \pi_n = \lim_{n\to\infty} \pi_n^w = 0$, this implies:

$$\begin{pmatrix} x_T \\ \pi_T \\ \pi_T^w \end{pmatrix} = \frac{1}{(1-\delta)} \sum_{n=T}^{\infty} A^{n-T} \begin{pmatrix} 1 \\ \mu_1\mu_2 \\ \mu_1^w\mu_2^w \end{pmatrix} \lambda_n \quad (A5)$$

$$A^n = \frac{1}{(1-\delta)^n}\begin{pmatrix} 1 & \theta & 0 \\ \mu_1\mu_2 & (\beta - \beta\delta + \theta\mu_1\mu_2) & 0 \\ \mu_1^w\mu_2^w & \theta\mu_1^w\mu_2^w & \beta(1-\varepsilon)(1-\delta) \end{pmatrix}^n = \begin{pmatrix} a_n & b_n & c_n \\ d_n & e_n & f_n \\ g_n & h_n & j_n \end{pmatrix} \quad (A6)$$

We can notice that: $(\forall n)\ c_n = f_n = 0 \qquad j_n = \beta^n(1-\varepsilon)^n$

Besides, using also equation (A2), we obtain the following economic variables:

$$x_T = -\frac{\theta}{(1-\delta)} i_T - \frac{\theta}{(1-\delta)}\left\{1 - \frac{[(1-\beta)+\delta\beta(1-\tau_{k,T})]}{[(1-\beta)+\delta\beta(1-\nu)(1-\tau_{k,T})]}\left(\frac{G_T}{Y_T}\right)\right\}\widehat{\tau_{c,T}} - \frac{[(1-\beta)+\delta\beta(1-\tau_{k,T})]}{(1-\delta)[(1-\beta)+\delta\beta(1-\nu)(1-\tau_{k,T})]}\widehat{\tau_{k,T}} + f\left(\sum_{n=T+1}^{\infty} i_n, \sum_{n=T+1}^{\infty}\widehat{\tau_{c,n}}, \sum_{n=T+1}^{\infty}\widehat{\tau_{k,n}}\right) \quad (A7)$$

$$\pi_T = \mu_1\mu_2 x_T \quad (A8)$$

$$\pi_T^w = \mu_1^w\mu_2^w x_T \quad (A9)$$

## Appendix B: Expression of All Other Economic Variables

According to equations (A8) and (A9), the variation in the real wage is as follows:

$$(w_T - p_T) = f\left((w_{T-1} - p_{T-1}), \sum_{n=T}^{\infty} i_n, \sum_{n=T}^{\infty}\widehat{\tau_{c,n}}, \sum_{n=T}^{\infty}\widehat{\tau_{k,n}}\right) \quad (B1)$$

Equations (15), (17), (37), (46), (47), the values of $(\varepsilon_T^{g,inv})$ and $(y_T^p = k_T + \widehat{\tau_{k,T}})$, equations (A7), (A8) and (A9) imply:

$$k_T = -\frac{\theta}{(1+\theta\varphi)}\widehat{\tau_{l,T}} + f(.) \quad (B2)$$

$$l_T^D = -\frac{\theta}{(1+\theta\varphi)}\widehat{\tau_{l,T}} + f(.) \quad (B3)$$

Using equations (12), (39), (B1), ($y_T^p = k_T + \widehat{\tau_{k,T}}$), (A7), (A8), (A9) and (B2), labor supply is:

$$l_T^S = -\frac{\theta}{(1+\theta\varphi)}\widehat{\tau_{l,T}} + f(.) \quad (B4)$$

Equations (37), (38), (39), (B2), ($y_T^p = k_T + \widehat{\tau_{k,T}}$), (A7), (A8) and (A9) imply:

$$y_T = -\frac{\theta}{(1+\theta\varphi)}\widehat{\tau_{l,T}} + f(.) \quad (B5)$$

$$inv_T = -\frac{\theta}{(1+\theta\varphi)}\widehat{\tau_{l,T}} + f(.) \quad (B6)$$

$$c_T = -\frac{\theta}{(1+\theta\varphi)}\widehat{\tau_{l,T}} + f(.) \quad (B7)$$

Detailed analytical values of all variables are available upon request from the author.