# Tax competition, fiscal policy and public debt levels in a monetary union

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*Summary*

*We study the link between tax competition, efficiency of available fiscal bases and public indebtedness levels in the member countries of a monetary union. Theoretically, labor taxation would be the most efficient to collect fiscal resources; so, only initially weakly indebted countries can afford to have weak labor taxation rates. Empirical data also validate the decreasing relation between consumption taxation rates and public debt levels. On the contrary, capital taxation would be less efficient. If the capital taxation rate is higher than in the rest of the monetary union, tax evasion could deteriorate the fiscal base and increase the public debt to GDP ratio. So, empirical data show an ambiguous trend between the historical evolution of implicit capital taxation rates and public debt levels in the Euro Area.*

**Keywords**: capital taxation rate, labor taxation rate, consumption taxation rate, public debt, monetary union, tax competition
**JEL-Codes**: F45, H63, H73, H87

## 1. Introduction

The consequences and the dangers of tax competition have been largely studied in the economic literature, and particularly in the framework of a monetary union where financial and commercial interdependencies are more accentuated. For example, in the context of the European Economic and Monetary Union (EMU), many studies feared that tax competition could conduct to a 'race to the bottom', reducing effective taxation rates on the more mobile fiscal bases (capital), and excessively increasing taxation rates on immobile fiscal bases (labor, land). Indeed, capital mobility reduces the incentive for source countries and the ability of residence countries to tax mobile activities. Residence countries have difficulties monitoring and taxing accrued income from foreign investment. At the same time, source countries are reluctant to impose high taxes on inward foreign investment for fear of provoking capital flight. Therefore, the attempts of governments to attract mobile capital may trigger a process of international tax competition, in which taxation and public spending is driven below the optimal level. Furthermore, living within a monetary union has probably increased the degree of mobility of factors; in the context of the European Economic and Monetary Union (EMU), there is now a higher degree of mobility of factors across member States, especially regarding capital.

More precisely, regarding the taxation of consumption, the destination principle usually prevails: exports are not taxed by the exporting country but by the importing country. The origin-based taxation system is applied for cross-border shopping only, which has a negligible share in total trade. In the same way, labor mobility remains quite low in Europe

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today. Therefore, tax competition mainly concerns the capital production factor. The economic literature has repeatedly provided evidence that capital movements have become more responsive to the level of capital taxation, implying a higher degree of tax competition among EMU member States. For example, regarding the taxation of capital which is a highly mobile factor, a country could have interest to conduct a 'beggar the neighbor' policy, reducing its tax rates, in order to attract a larger tax base; and tax rates are then fixed un-cooperatively at an inefficiently low level. Therefore, such a situation of tax competition was feared from the very beginning of the creation of the EMU.

However, this apprehension was not really verified empirically. Indeed, even capital is not a perfectly mobile production factor. Capital cannot move easily from one country to another, in particular if a production technology requires specific and high skill workers (who are much less mobile), if it concerns the production of non-tradable goods and mainly services, or if a country can benefit from location rents. The competitiveness of a country (agglomeration forces) and other strategies also determine capital inflows. So, some studies have underlined that despite tax competition, capital taxation should persist in the future and remain at non negligible levels, in particular in order to capture these unusual profits and location rents. Besides, political forces and motivations may also avoid the decrease of capital taxation rates below a given level, and capital still continues to be taxed in all major economies. Nevertheless, if the risk of a fall in capital taxation rates to excessively low levels has not been verified empirically, tax competition is not immune of important consequences for very open countries, mainly in the framework of a monetary union. In particular, the effect of financial globalization on the governments' ability to redistribute or on the public debt level is an important yet only partially understood issue.

Regarding the capital production factor, what could be the consequences of a higher economic integration? The 'efficiency hypothesis' predicts that competing for mobile tax bases, the national tax rate on a mobile factor should be eroded. Indeed, a source-based tax on the mobile factor (capital) appears as counter-productive and inefficient, as it could strongly decrease the fiscal base (the capital stock). So, this potential outflow of capital implies that the fiscal burden mainly relies on local residents in the form of higher taxes on labor or land property, or higher prices for non-tradable goods, if the country wants to preserve a given level of fiscal resources and to maintain the production of a given level of public goods and services. Besides, the 'compensation hypothesis' mentions that governments could increase their social and welfare expenditure in order to insure the citizens against the increased economic risk generated by globalization. Therefore, more than the danger to see a decrease of taxation rates on mobile fiscal bases to excessively low and near zero levels, tax competition has redistribution issues and important implications regarding the evolution of the public indebtedness level.

The economic literature has shown that increased capital mobility and tax competition have conducted to a shift of the fiscal burden to labor, as taxes on capital are reduced in order to attract the more mobile capital and to increase the fiscal base. Labor and consumption tax bases are quite immobile, and may not fly abroad to avoid the fiscal burden. However, as mentioned by Genschel (2001), a high unemployment rate or the shadow economy may then represent another kind of potential fiscal evasion if taxation rates on these more immobile bases are too high. Indeed, tax competition prevents governments from tapping into important sources of capital tax revenue and forces them to rely more on labor taxation to meet fiscal resources targets. This had detrimental repercussions on employment and growth, and on the possibility to conduct a redistributive economic policy. According to the author, because of internal pressures to avoid an excessive weight on the labor production factor, the public deficit and the public debt increase, there is more austerity, more unemployment, and the

shadow economy is strongest than in a world without tax competition. Therefore, the aim of the current paper is to study the potential consequences of tax competition for the evolution of the budgetary deficit and for the dynamic evolution of the public debt in the framework of a monetary union. Indeed, the role of government debt as a determinant of fiscal policy and tax competition has often been ignored in the economic literature.

The rest of the paper is organized as follows. The second section recalls the results of the economic literature regarding the links between fiscal policy, tax competition and the public debt levels in the member countries of a monetary union. The third section describes the New-Keynesian model used to shed light on this question: the economic agents, as well as the global equilibrium of this model. The fourth section defines the theoretical economic and fiscal (capital, consumption or labor taxation rates) factors that could influence the public debt level. The fifth section reviews empirical data related to this link between taxation rates and public debt levels. Finally, the sixth section concludes the paper.

## 2. The economic literature

One of the main result of the economic literature is to underline that tax competition should influence the instruments of fiscal policy, as it should shift the fiscal burden from mobile to less mobile fiscal bases. A higher capital mobility is supposed to generate a race to the bottom in taxes on mobile capital taxed at source; consequently, the corporate tax rate is expected to depend negatively on the degree of capital mobility, whereas personal income taxes on immobile labor increase. In this context, Sorensen (2001) mentions that labor taxes (personal income taxes related to labor, payroll taxes, social security taxes) have risen between the 1980s and the 2000s, whereas capital taxes (taxes on corporate income, taxes on personal income related to property, wealth, etc.) remained much more stable. Therefore, whereas tax competition does not conduct to an under-provision of public goods, it would imply an unfair distribution of the tax burden to the detriment of the immobile labor. Sorensen (2003) also shows that between 1985 and 1995, when international capital flows increased considerably, the increase in the overall tax burden experienced in most countries was concentrated on labor, suggesting that increasing capital mobility induced governments to raise the relative tax burden on the more immobile labor factor.

Zodrow (2006) also examines the taxation of capital income in a small open economy that faces a highly elastic supply of internationally mobile capital and increasing tax competition. In this context, he underlines that according to many authors, a source-based capital income taxation (corporate income tax) is particularly undesirable because it is a highly distortionary tax instrument, relative to other potential revenue sources. Indeed, as capital is mobile and will migrate out of the country if taxation rates are excessive, the local factors of production (immobile labor and land) ultimately bear the entire burden of the capital income tax, including its efficiency costs. In the same way, Bretscher and Hettich (2002) show that the effect of globalization is positive on the ratio of the effective labor tax rate over the corporate tax rate, verifying the shift from corporate tax to less mobile tax bases for OECD countries. They study a panel of 14 OECD countries for the period 1967-96. Then, they find that globalization (indicator of integration in the world economy) has indeed a negative and significant impact on statutory corporate taxes, and tends to raise labor taxes which are less elastic.

Sorensen (2003) shows that between the 1970s and the 1990s, falling statutory corporate tax rates have been roughly offset by a broadening of the corporate tax base so that corporate tax revenues have been fairly stable as a fraction of GDP in most countries. Nevertheless, between 1985 and 1995, where international capital flows increased

considerably, the increase in the overall tax burden experienced in most countries was concentrated on labor. In the same way, in conformity with their theoretical model, using empirical data for 23 OECD countries between 1980 and 2001, Haufler *et al.* (2006) show that countries reduce their corporate tax rate relative to the labor taxation rate, either when preferences for public goods increase (higher share of public consumption in GDP) or when a rising share of capital is employed in multinational firms. Empirically, Krogstrup (2004) also tries to use a global multi-aspect index of capital mobility (Quinn 14), less controversial theoretically than a unique indicator of this mobility. Then, he shows robust evidence in favor of a tax competition effect on corporate tax burdens in 13 European Union countries between 1980 and 2001.

In the same way, using data of the Bureau of Labor Statistics for 13 OECD countries between 1980 and 2004, the econometric analysis of Azémar and Hubbard (2015) shows that a substantial share of the corporate tax burden is shifted from capital to labor. Indeed, they find that a 1% point increase in corporate taxes decreases wages by approximately 0.1%. However the magnitude of this shift is strongly driven by country characteristics influencing the mobility of capital and by the world price of output. Indeed, the decrease in domestic capital reduces the productivity of domestic workers, which translates (indirect effect) into lower wages at home. Therefore, according to the authors, the domestic labor's burden would be lower, the lower the degree of trade openness, but the higher the relative position of a country in the world capital market and in the world market supply. The domestic labor's burden would also be lower, the lower the level of depreciation allowances and when the corporate income tax is residential-based (context of a tax-credit system).

Using data for 30 countries between 1979 and 2002, Felix (2017) estimates that a 1% point increase in the marginal corporate tax rate of high-income countries reduces mean annual gross wages by 0.7%; it concerns wages of low-skill and high-skill workers to the same degree. Hassett and Mathur (2006) also investigate the incidence of various measures of corporate tax rates on manufacturing wages with panel data across 72 developed and developing countries between 1981 and 2002, and they find that labor is substantially affected by corporate tax rates. Indeed, the average corporate tax rate for all countries went down from 42% in 1981 to around 29% in 2000, whereas for the same period, average wage rates increased from 3.5 dollars per hour to 6 dollars per hour. So, an increase by 1% in the statutory corporate tax rate decreases wages by 0.95% on average across the estimations. Besides, the magnitude of the impact would be amplified for poor and small economies. On the contrary, the authors don't find any effect of personal income tax rates on wages.

A last explanation of the increase in labor taxation rates can be found in the following paper. Examining companies located in nine European countries over the period 1996–2005, Arulampalam *et al.* (2008) underline the importance of the wage bargaining process between employers and trade-unions (employees) on the sharing of the Value Added Tax and of quasi-rents generated by the production process. So, they find that in the long run, conditional on a given Value Added to be shared, an exogenous rise of 1$ in corporate tax would reduce the wage bill by 75 cents.

However, despite the tendency to shift the fiscal burden on less mobile fiscal bases, capital taxation rates have remained and could remain in the future at non negligible levels in developed countries and in the biggest European countries, mainly because of 'location specific rents'. Indeed, using a panel data set on Western European countries, Baldwin and Krugman (2004) show that agglomeration forces can reverse standard international-tax-competition results, as they create quasi-rents that can be taxed without inducing delocalization. This suggests that the tax game is something subtler than a race to the bottom. Indeed, advanced nations benefit from advantages like an established base of infrastructure,

accumulated experience… which imply favorable external economies, allowing them to have higher taxation rates even on mobile capital than less advanced nations. In the same way, Cai and Treisman (2005) show that if countries or regions are sufficiently heterogeneous in natural resources, geographical location, inherited human capital or infrastructure, capital mobility often weakens discipline on the poorly-endowed units and increases policy divergence. While better-endowed units do invest more in infrastructure—and are rewarded by capital inflows—poorly endowed units may actually be less business friendly or more corrupt than under capital immobility.

Therefore, many papers show that location decisions of multinational firms are mainly influenced by the local market and the institutional conditions of the host country. Fundamental factors include proximity to markets, the costs of various primary and intermediate inputs, the skill levels available in local labor markets, the local competitive, legal and regulatory environment, and the degree of political stability including the credibility of commitments to enforce property rights. For example, Garretson and Peeters (2006) study 19 OECD countries between 1981 and 2001. Their main conclusion is then that increased international capital mobility (measured by the volume of FDI) implies a lower corporate tax rate. Nevertheless, they also underline that core countries can afford higher tax rates compared to peripheral countries, because agglomeration of economic activities (measured by population per $km^2$) matters.

Kind *et al.* (2000) also use a new economic geography model to analyze tax competition between two countries trying to attract internationally mobile capital. Each government may levy a source tax on capital and a lump sum tax on fixed labor. So, if industry is concentrated in one of the countries, the authors find that the host country will gain from setting its source tax on capital above that of the other country. In particular, the host country may increase its welfare per capita by setting a positive source tax on capital and capture the positive externality that arises in the agglomeration. Capital becomes effectively immobile due to pecuniary externalities arising in the agglomeration. Sorensen (2006) names 'location specific rents' these rents which are due to the existence of natural resources, an attractive infrastructure, availability of a pool of qualified labor and, more generally, the existence of 'agglomeration forces'. These forces explain why corporate taxes will not disappear even in a framework of capital mobility. In fact, whereas 'normal' returns on capital are difficult to tax and could tend to vanish (they are empirically very weak today), these 'specific rents' on capital could still continue to be taxed in the future.

Therefore, in this framework, many papers find that empirically, tax competition didn't conduct to the huge decrease in capital taxation rates that was feared. For example, Devereux and Sorensen (2006) show that statutory corporate tax rates have fallen substantially since the early 1980s; while the pace of reductions has varied over time, it appears to be continuing, probably because of competitive pressure. However, tax bases were broadened between the early 1980s and the end of the 1990s; therefore, on average, weighted by GDP, tax revenues on corporate income have remained broadly stable as a proportion of GDP between 1965 and 2000. Nevertheless, tax revenues on corporate income have declined as a proportion of total tax revenue since 1965. In the same way, Devereux *et al.* (2002) note that average statutory corporate income tax rates in the European Union and in the United States fell dramatically from 48% in 1982 to 35% in 2001. At the same time, these rate reductions have often been accompanied by base-broadening efforts, so that overall corporate tax revenues in proportion of GDP as well as average and especially marginal effective tax rates have declined considerably less. More precisely, Devereux *et al.* (2002) establish a number of stylized facts about the development of taxes on corporate income in European Union (EU) and G7 countries between 1980 and 2002. They show that tax-cutting and base-

broadening (less generous allowance rates) reforms have had the effect that, on average, effective tax rates on marginal investment have remained fairly stable, but those on more profitable investments (location of attractive and more mobile multinationals) have fallen.

In the same way, Hines (2007) shows that despite growing international capital mobility, and various fiscal practices to attract this capital, corporate tax collections are remarkably persistent relative to gross domestic product (GDP), government revenues, or other indicators of underlying economic activity or government need. According to the author, it seems that less mobile national capital has continued to be highly taxed, while the tax burden has decreased in order to attract the more mobile international investors. In fact, corporate tax revenues as a fraction of GDP in OECD countries have been roughly constant over the past 40 years, and they have even increased around 2010 (Devereux, 2007). Bond *et al.* (2000) also show that between 1980 and 2000, corporate tax revenues have not decreased in proportion of GDP. Indeed, several countries have financed rate reductions by making depreciation allowances less generous and/or by eliminating other deductions (broader basis). Slemrod (2004) also finds that increase in openness and international competitive pressures seem negatively associated with statutory corporate rates between 1980 and 1995. On the contrary, he finds clear evidence that the corporate tax rate is insulated from a country's revenue needs (expenditure–GDP ratio)

More precisely, while there was a period of strong corporate tax rate reductions, in particular around the time of the Eastern enlargement of the EU, this process has been slowed down significantly after 2005. Indeed, taken into account that the completion of the single market generally increased the attractiveness of Europe for international investment, it seems plausible that EU member States can maintain their now moderate level of corporate taxation in the future, even in a framework of international tax competition. If capital mobility puts a downward pressure on statutory corporate tax rates, more integrated and open countries may be tempted to increase taxation rates on capital in order to tax foreign firms and to export part of the fiscal burden to these big multinationals (tax exportation effect). Therefore, by broadening the tax base, effective tax rates on capital (the share of capital taxation in GDP) remained high even in a context of a decrease in statutory tax rates, between 1980 and the 2000s (Sorensen, 2000 and 2006).

Besides, between 1971 and 1995, using empirical data for the G7 countries, Mendoza and Tesar (2005) find evidence of tax competition between countries, as financial liberalization increases the covariance and the co-movement between taxation rates in G7 countries, conducing to a welfare loss in all countries. The authors also find that harmonization of indirect taxation is undesirable because it forces countries to respond to the adverse effects of tax competition on tax revenues by raising highly distorting labor income taxes. Harmonization of taxation on immobile factors and freedom to adjust consumption taxes to make up for the tax revenue lost because of capital income tax competition would be far more desirable. Therefore, with this study, the authors underline that tax competition has also consequences for the redistribution of the collection of fiscal resources, passing through the danger to increase the budgetary deficit and the public debt.

In the same vein, Arcalean (2017) finds that international financial liberalization increases capital mobility and hinders redistribution from capital to labor in every period. A higher share of the fiscal burden is shifted from capital towards labor. Therefore, raising the public debt can lower the overall tax burden on labor, and allows a higher redistribution. In this condition, stronger tax competition leads to a fiscal deficit bias at the early stages of financial liberalization, driven by the median voter's preference for redistribution. Holding capital mobility constant, fiscal deficits increase in the number of countries joining the integrated capital market. International asymmetries in capital mobility also lead to external

imbalances and diverging fiscal deficits across countries; the bias towards fiscal deficits is worsened in countries that experience relatively low costs of investing abroad.

Furthermore, Janeba and Todtenhaupt (2016) develop a simple model of fiscal competition with government borrowing. If a default on government debt is no option, initial debt levels play no role in fiscal competition. To the contrary, a government can be constrained in its borrowing, due to a possible default, or simply because of common rules of fiscal discipline (like the Fiscal Compact in the European Union). Therefore, in these conditions, a government responds optimally by lowering spending on durable public infrastructure, which in turn induces more aggressive tax setting. So, such a model may help to explain the observation that highly indebted countries in Europe have decreased corporate tax rates over-proportionally, and have infrastructure which continue to deteriorate. Besides, a rise in exogenous firm mobility reinforces the link between legacy debt and fiscal competition. The cut in capital taxation rates risks to be all the more aggressive as the high inherited public debt level is due to high previous public consumption expenditure, with an insufficient level of public investment expenditure in infrastructure.

In the line of these studies, the current paper aims at shedding a new light on the links between tax competition and public debt levels in a monetary union. Its goal is to show in which way a higher financial integration and tax competition can affect fiscal policies and the public debt levels of the member countries in the framework of a monetary union.

## 3. The model

Our study will adopt the standard framework of a small New-Keynesian model, with a representative household, a representative firm and a government in a given country (i). Our goal is to study the context of a monetary union in open-economy, where many countries share a same currency and a same central bank, in order to analyze the specificity of the European Economic and Monetary Union (EMU). Therefore, our model considers the situation of a given country (i), whereas the 'country (j)' represents all other countries and the rest of the whole monetary union.

We suppose that economies are perfectly competitive, goods market are perfectly integrated, and financial capital is perfectly mobile. Financial markets are assumed to be complete both at the national and international level in this monetary union (risks are fully shared among households), and countries share the same common interest rate. This common interest rate is defined by the monetary policy of the common central bank, whereas each government defines autonomously its fiscal policy (public expenditure, tax revenues and public debt). In each member country, the government maximizes the utility of a representative consumer /household; public expenditure is, therefore, an endogenous variable in our model. Besides, while there is free international movement of capital, labor markets are segmented, and labor is supposed to be immobile across countries. Each country may levy taxes on wage (including social security taxes), indirect taxes on consumption, and taxes on capital income. Income distribution issues are ignored by assuming either that each region's residents are identical or that their aggregate welfare can be depicted by the preferences of a 'representative consumer'. Productivity, taxation rates, public expenditure or public indebtedness can differ between countries; however, for simplicity, all countries in the monetary union share the same preferences and structural parameters.

Furthermore, in the current paper, we suppose that capital is mainly taxed according to the source base principle. Indeed, taxing residents on their world-wide capital income equally, according to the residence principle, is very difficult empirically: administrative and tax compliance problems involved in taxing foreign source income, imperfect exchange of

information among the tax authorities, persistence of bank secrecy laws, etc. Besides, in the area of corporate income taxation, many residence countries explicitly exempt foreign-source income from domestic tax if the foreign income originates from a tax treaty partner country, and most other countries only tax the foreign-source income of their 'resident' multinationals to the extent that this income is repatriated to the parent company, and only in so far as the domestic tax liability exceeds the source tax which has already been paid to the foreign country. So, we make the hypothesis that at least regarding (corporate) taxes on capital, residents of a country are not taxed on their income from foreign sources and that foreigners are taxed equally as residents on income from domestic sources.

## 3.1. The representative consumer

Aggregate demand for the country (i) results from the log-linearization of the Euler equation, which describes the representative household's expenditure decisions. The representative household/ consumer in the country (i) provides labor and it consumes goods. In a given period (T), it maximizes an inter-temporal utility function:

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

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

We suppose that the utility function of a representative household has the form:

$$U_{i,t} = \alpha_c log(C_{i,t}) + \alpha_g log(G_{i,t}) - \alpha_l \frac{1}{(1+\varphi)} L_i^{(1+\varphi)} \qquad (2)$$

With: ($C_{i,t}$): real consumption of private goods; ($G_{i,t}$): real public expenditure (consumption of public goods); ($L_i$): Labor supply (fixed as labor is immobile).
The indices ($0<\alpha_c<1$) ($0<\alpha_g<1$) and ($0<\alpha_l<1$) are the respective weights given by the representative consumer to consumption of private goods, public goods and leisure.

Utility is an increasing and concave function of ($C_{i,t}$), an index of the household's private consumption of all goods that are supplied, and of public goods and services provided in the home country ($G_{i,t}$). Utility is also a decreasing and convex function of labor supply ($L_i$), where ($\varphi \geq 0$) is the inverse of the Frisch elasticity of labor supply.

This maximization is subject to the life time and inter-temporal budgetary constraint. If we suppose complete financial markets, the flow budget constraint for each period (T) of the representative consumer in the country (i) is as follows:

$$(1+t_i^c)P_{i,T}C_{i,T} + P_{i,T}INV_{ii,T} + P_{j,T}INV_{ij,T} + B_{i,T} = \left(1-t_i^k\right)(R_T - \delta P_{i,T})K_{ii,T}^s + \left(1-t_j^k\right)(R_T - \delta P_{j,T})K_{ij,T}^s + \left(1-t_i^l\right)W_{i,T}L_i + (1+R_{T-1})B_{i,T-1} \qquad (3)$$

With, in the country (i) in period (t): ($INV_{ij,t}$): real investment of households from country (i) in new physical capital in country (j); ($K_{ij,t}^s$): physical capital belonging to households in country (i) invested in country (j); ($P_{i,t}$): consumer prices; ($W_{i,t}$): nominal wage rate; ($R_t$): nominal interest rate common to all countries in the monetary union; ($B_{i,t}$): nominal value of government' bonds and public debt at the end of period (t); (δ): depreciation rate of physical capital; ($t_i^l$): labor taxation rate; ($t_i^c$): consumption taxation rate; ($t_i^k$): capital taxation rate.

Indeed, the representative consumer may consume his non-human wealth immediately, or he may invest it on the capital market and consume it at the end of the period. So, regarding his expenditure, the representative consumer of the country (i) consumes private

goods, and he invests in capital or he purchases government' bonds. The share of his revenues that the representative consumer does not spend on consumption of private goods (saving) is the share that he can invest on the capital market. Regarding his resources, he receives labor (wage) and capital (interest rate) revenues. Indeed, we suppose that capital is rented by households to firms, for which they receive a rental rate. The representative consumer also receives gains from government bonds holding from the previous period. For simplicity, we suppose that these financial assets are only riskless one-period government bonds, and that the public debt of the country (i) is fully owned by domestic consumers. Besides, capital is not fully taxed: physical capital depreciation is exempted from taxation.

In this context, the maximization of equation (1) using (2) under the constraint (3) implies the following first order Euler condition, regarding timing of expenditure decisions and inter-temporal substitution, for whatever period (T)[2]:

$$\frac{\partial U_{i,T}}{\partial C_{i,T}} = \frac{\beta^k E_T[(1+R_{T+k-1})\dots(1+R_T)]P_{i,T}}{E_T(P_{i,T+k})}\frac{\partial E_T(U_{i,T+k})}{\partial C_{i,T+k}} \quad (4)$$

Furthermore, by combining equations (2) and (4), (VT), (Vk), we have:

$$C_{i,T} = \frac{E_T(P_{i,T+k})}{\beta^k E_T[(1+R_{T+k-1})\dots(1+R_T)]P_{i,T}} E_T(C_{i,T+k}) \quad (5)$$

So, in logarithms and in variations from their long run equilibrium values, with log(1+x)~x provided (x) is sufficiently small; with $[\pi_{i,t} = p_{i,t} - p_{i,t-1} = \frac{P_{i,t}-P_{i,t-1}}{P_{i,t-1}}]$: inflation rate for consumption prices; equation (5) implies:

$$c_{i,T} = E_T(c_{i,T+1}) - [R_T - E_T(\pi_{i,T+1})] \quad (6)$$

So, private consumption increases with expected future consumption, and it decreases with the real interest rate.

Besides, for the representative consumer in the country (i), according to equation (2), we obtain the following optimal substitution (such as: $\partial U_{i,T} = 0$) between private and public consumption:

$$G_{i,T} = -\frac{\alpha_g}{\alpha_c}\left(\frac{\partial G_{i,T}}{\partial C_{i,T}}\right)C_{i,T} \quad (7)$$

So, regarding the variation in private and public consumption, according to equation (7), in logarithms and in variations from their long run equilibrium values, we obtain:

$$g_{i,T} = c_{i,T} \quad (8)$$

Moreover, for a given level of labor supply (we take the demographic situation and the population size of a country as given), according to equation (2), the public debt that maximizes the utility of the representative consumer in the country (i) $[\frac{\partial U_{i,t}}{\partial B_{i,t}} = 0]$ verifies:

$$-\alpha_c G_{i,t}\left(\frac{\partial C_{i,t}}{\partial B_{i,t}}\right) = \alpha_g C_{i,t}\left(\frac{\partial G_{i,t}}{\partial B_{i,t}}\right) \quad (9)$$

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[2] Summing (3) to have an intertemporal budgetary constraint, and using equation (10), with $\lim_{T\to\infty} B_{i,T}=0$, we have:

$$(1+t_i^c)P_{i,T}C_{i,T} + E_T[\sum_{t=T}^{\infty}\frac{(1+t_i^c)P_{i,t+1}C_{i,t+1}}{(1+R_t)\dots(1+R_T)}] + f(\sum_{t=T}^{\infty}K_{il,T}^s, \sum_{t=T}^{\infty}K_{ij,T}^s)$$
$$= (1-t_i^l)W_{i,T}L_i + E_T[\sum_{t=T}^{\infty}\frac{(1-t_i^l)W_{i,t+1}}{(1+R_t)\dots(1+R_T)}]L_i + (1+R_{T-1})B_{i,T-1} < \infty.$$

So, the loss in terms of weaker purchasing power and private consumption of a higher taxation rate, higher fiscal resources and a weaker public debt level must equal the gains in terms of higher provided public services if the public indebtedness increases. The marginal rate of transformation between private and public consumption must equalize the marginal rate of substitution between them in the utility function of the representative consumer.

Finally, we suppose that the capital stock varies according to the following equation:

$$E_t(K_{ij,t+1}) = (1-\delta)K_{ij,t} + INV_{ij,t} \qquad (10)$$

So, in logarithms and in terms of variations, the capital stock adjusts as follows:

$$E_t(k_{ij,t+1}) = (1-\delta)k_{ij,t} + \left(\frac{INV_{ij}}{K_{ij}}\right) inv_{ij,t} = (1-\delta)k_{ij,t} + \delta inv_{ij,t} \qquad (11)$$

## 3.2. The representative firm

We suppose a continuum of firms in the country (i). The representative firm produces a differentiated good in a monopolistic competition setting. 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. The representative firm in the country (i) produces with the help of two production factors: capital (from domestic or foreign source) and labor, which respective shares in the production function are ($0<\nu<1$) and ($0<1-\nu<1$). We assume that marginal products are positive and diminishing, and that all factors are complement in the production function. Besides, public expenditure is also a factor raising public input; production increases with public goods and services supplied by the government in the country (i), according to the parameter (z). We assume that all corporate taxes are included in the capital income tax levied on households. So, the production function has the following form, for the representative firm in the country (i):

$$Y_{i,t} = F_i\left(K_{ii,t} + K_{ji,t}, L_i\right) = A_{i,t}(K^d_{.i,t})^{\nu}(L_i)^{1-\nu}G^z_{i,t} \qquad (12)$$

With, for the country (i) in period (t): ($A_{i,t}$): technology or productivity shock, common to all firms in the country; ($Y_{i,t}$): real economic activity.

This representative firm maximizes its nominal profit:

$$\Pi_{i,t} = P_{i,t}Y_{i,t} - R_tK^d_{.i,t} - W_{i,t}L_i \qquad (13)$$

Production factors are paid at their marginal products, and we suppose constant returns. So, the maximization of the profit in equation (13) implies:

$$P_{i,t}\frac{\partial Y_{i,t}}{\partial K^d_{.i,t}} = \nu A_{i,t}P_{i,t}(K^d_{.i,t})^{-(1-\nu)}(L_i)^{1-\nu}G^z_{i,t} = R_t > 0 \qquad (14)$$

$$P_{i,t}\frac{\partial Y_{i,t}}{\partial L_i} = (1-\nu)A_{i,t}P_{i,t}(K^d_{.i,t})^{\nu}(L_i)^{-\nu}G^z_{i,t} = W_{i,t} > 0 \qquad (15)$$

Therefore, by combining equations (14) and (15), we obtain the following relation between the nominal wage and the interest rate in the country (i):

$$W_{i,t} = \frac{(1-\nu)K^d_{.i,t}}{\nu L_i}R_t \qquad (16)$$

Besides, households are free to invest their capital wherever they want. So, assuming rational behavior, capital moves across borders to seek the highest net-of-tax return. Allocation is then defined according to post-tax rates of return, which are equated across countries. So, when the representative consumer choses his investment, the profitability of private firms decreased by the taxation rate that he will have to pay on this profitability must

be the same across all firms in the member countries, and equal to the world real capital rate of return (ρ) defined on the world financial market according to the world interest rate. So, we have the following 'capital arbitrage condition':

$$\frac{R_t}{P_{i,t}}\left(1-t_i^k\right)=\frac{R_t}{P_{j,t}}\left(1-t_j^k\right)=\rho \qquad (17)$$

As $[\frac{\partial(\frac{R_t}{P_{i,t}})}{\partial t_i^k}=\frac{\rho}{\left(1-t_i^k\right)^2}>0]$, the required before-tax real interest rate increases with the capital taxation rate, in order to obtain the same post-tax real return.

Furthermore, by combining equations (14) and (17), we obtain:

$$\left(K_{ii,t}^d+K_{ji,t}^d\right)=\frac{\nu^{\frac{1}{(1-\nu)}}\left(A_{i,t}\right)^{\frac{1}{(1-\nu)}}(L_i)G_{i,t}^{\frac{z}{(1-\nu)}}\left(1-t_i^k\right)^{\frac{1}{(1-\nu)}}}{\rho^{\frac{1}{(1-\nu)}}} \qquad (18)$$

Therefore, equation (18) implies[3]:

$$\frac{\partial\left(\mathrm{K}_{ii,t}+K_{ji,t}\right)}{\partial t_i^k}\frac{t_i^k}{\left(\mathrm{K}_{ii,t}+K_{ji,t}\right)}=-\frac{t_i^k}{(1-\nu)\left(1-t_i^k\right)}<0 \qquad (19)$$

Equation (19) is the tax elasticity of the demand for capital, the percentage change in the demand for capital in a given country in response to a 1% increase in its own capital tax rate, which is negative. It is larger (more negative) the higher the national taxation rate. So, there is tax evasion, as a higher taxation rate in a given country implies a leakage of the tax base. A higher taxation rate has consequences on the tax base in an open economy; there is an outflow of capital if the taxation rate increases. Indeed, a higher taxation rate lowers the net marginal product in the national country, and causes capital to relocate towards the remaining countries. Another explanation is to observe that in a small open economy, a source-based tax on capital income pushes up the required pre-tax rate of return, leaving the post-tax rate of return unaffected. So, such a process usually requires a reduction in the stock of capital.

Furthermore, using equations (16), (17) and (18), we obtain[4]:

$$\frac{\partial\left(\mathrm{K}_{jj,t}+K_{ij,t}\right)}{\partial t_i^k}\frac{t_i^k}{\left(\mathrm{K}_{jj,t}+K_{ij,t}\right)}=0 \qquad (20)$$

$$\frac{\partial W_{i,t}}{\partial t_i^k}\frac{t_i^k}{W_{i,t}}=-\frac{\nu t_i^k}{(1-\nu)\left(1-t_i^k\right)}<0 \qquad (21)$$

So, the nominal wage falls in response to a higher capital taxation rate in the national country. Indeed, source-based capital income taxes raise the required pre-tax rate of return on capital, so that at the margin the post-tax rate of return is still equal to the world rate of return. In turn, such taxes thus tend to drive away capital and consequently to depress wages or to reduce employment; therefore, the labor force bears the effective incidence of such taxation.

Besides, we consider a Calvo-type framework of staggered prices, where a fraction (0<α<1) of goods prices remain unchanged each period, whereas prices are adjusted for the remaining fraction (1-α) of goods. Monopolistically competitive firms choose nominal prices

[3] With ($t_i^k=0.3$) and (ν=0.33), this is consistent with an elasticity of: $(\frac{\partial\left(\mathrm{K}_{ii,t}+K_{ji,t}\right)}{\partial t_i^k}\frac{t_i^k}{\left(\mathrm{K}_{ii,t}+K_{ji,t}\right)})$=-0.65, near the one mentioned in the following section 3.5 for the basic calibration of our parameters.

[4] $W_{i,t}=\frac{(1-\nu)\nu^{\frac{\nu}{(1-\nu)}}P_{i,t}\left(A_{i,t}\right)^{\frac{1}{(1-\nu)}}G_{i,t}^{\frac{z}{(1-\nu)}}\left(1-t_i^k\right)^{\frac{\nu}{(1-\nu)}}}{\rho^{\frac{\nu}{(1-\nu)}}}$.

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:

$$Min_{\,p_{i,t}^{i}} \sum_{k=0}^{\infty} (\alpha\beta)^k E_t(p_{i,t}^r - \widetilde{p_{i,t+k}^r})^2 \qquad (22)$$

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

The firm minimizes expected losses in profit for all future periods (t+k) due to the fact that it will not be able to set a frictionless optimal price in this period (t+k).These losses are subject to the actualization rate (β), as closer profits are given a higher weight than more distant ones. Besides, the probability that the price $(p_{i,t})$ will be fixed for (k) periods, until the period (t+k), is $(\alpha^k)$. Thus, by deriving in function of the reset price $(p_{i,t}^r)$, we have:

$$p_{i,t}^r = (1 - \alpha\beta) \sum_{k=0}^{\infty} (\alpha\beta)^k E_t(\widetilde{p_{i,t+k}^r}) \qquad (23)$$

Therefore, the representative firm in the country (i) sets the optimal reset price $(p_{i,t}^r)$ 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 this firm is to fix prices at marginal costs: $(\widetilde{p_{i,t}^r} = mc_{i,t})$, where $(mc_{i,t})$ is the nominal marginal production cost of the firm. Furthermore, prices in period (t) are an average of past prices and reset prices:

$$p_{i,t} = \alpha p_{i,t-1} + (1 - \alpha) p_{i,t}^r \qquad (24)$$

So, by combining equations (23) and (24)[5], we obtain the following equation regarding inflation for producer prices in the country (i):

$$\pi_{i,t} = \beta E_t(\pi_{i,t+1}) + \frac{(1-\alpha)(1-\alpha\beta)}{\alpha}(mc_{i,t} - p_{i,t}) \qquad (25)$$

Inflation then 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 reset by firms are increased.

Equation (12) gives the nominal production costs $(W_{i,t}L_i)$ and $(R_t K_{i,t}^d)$ for the production of the quantity $(Y_{i,t})$ for a representative firm in the country (i). So, by differentiating these equations and using equations (12), (14) and (15), the nominal marginal production cost of the quantity $(Y_{i,t})$ is as follows:

$$MC_{i,t} = \frac{\partial(W_{i,t}L_i)}{\partial Y_{i,t}} = \frac{\partial(R_t K_{i,t}^d)}{\partial Y_{i,t}} = \frac{R_t^{\nu} W_{i,t}^{1-\nu}}{\nu^{\nu}(1-\nu)^{1-\nu} A_{i,t} G_{i,t}^z} \qquad (26)$$

So, in logarithms and in variations from their long run equilibrium values, using equations (12), (17) and (26), we obtain the following variation in the real marginal production cost[6]:

$$(mc_{i,t} - p_{i,t}) = (1-\nu)(w_{i,t} - p_{i,t}) + \nu(r_t - p_{i,t}) - a_{i,t} - z g_{i,t} = 0 \qquad (27)$$

Therefore, according to equations (25) and (27), the Phillips supply curve of our DSGE model can be reduced to the following expression:

$$\pi_{i,t} = \beta E_t(\pi_{i,t+1}) \qquad (28)$$

The current inflation rate then only depends on the anticipated future inflation rate.

---

[5] $p_{i,t}^r = \frac{1}{(1-\alpha)} p_{i,t} - \frac{\alpha}{(1-\alpha)} p_{i,t-1} = \alpha\beta E_t(p_{i,t+1}^r) + (1-\alpha\beta)\widetilde{p_{i,t}^r} = \frac{\alpha\beta}{(1-\alpha)} E_t(p_{i,t+1}) + (1 - \alpha\beta)\widetilde{p_{i,t}^r} - \frac{\alpha^2\beta}{(1-\alpha)} p_{i,t}$.

[6] Equations (12), (14), (15) and (17) imply: $\nu = \frac{R_t K_{i,t}^d}{P_{i,t} Y_{i,t}} \approx \frac{\rho}{(1-t_i^k)} \frac{K_{i,t}^d}{Y_{i,t}}$; $(1-\nu) = \frac{W_{i,t} L_i}{P_{i,t} Y_{i,t}}$.

(12) implies: $y_{i,t} = a_{i,t} + \nu k_{i,t}^d + z g_{i,t}$; $k_{i,t}^d = y_{i,t}$ and $w_{i,t} = p_{i,t} + y_{i,t}$ (see above); $r_t = p_{i,t} = p_{j,t}$ (17).

## 3.3. Budgetary and monetary policies

The levels of public expenditure and taxation rates are fixed at the national level by the budgetary authorities. For simplicity, we suppose that all government debt is held domestically, and is risk free real debt (not state contingent), in conformity with most empirical observations. The government is supposed to be able to credibly commit to repay the public debt. Finally, we also suppose that taxation rates are time-invariant. For the government of the country (i), the budgetary constraint is then the following:

$$B_{i,t} = (1 + R_{t-1})B_{i,t-1} + P_{i,t}G_{i,t} - t_i^c P_{i,t}C_{i,t} - t_i^l W_{i,t}L_i - t_i^k(R_t - \delta P_{i,t})(K_{ii,t} + K_{ji,t}) \quad (29)$$

The public debt of the country (i) in period (t) equals the public debt of the former period (t-1) increased by the interest rate on this former public debt, plus the public expenditure of the current period to be financed, decreased by fiscal resources of the current period. In a source-based taxation system, the latter include consumption and labor taxation, and capital taxation on national and foreign capital invested in the national country, taking into account that physical capital depreciation is exempted from taxation.

In real terms and in proportion of the nominal GDP ($Y_{i,t}$), using equations (17) and (29) and the constant respective shares of the production factors in footnote 8, we have:

$$\left(\frac{B_{i,t}}{P_{i,t}Y_{i,t}}\right) = \frac{(1 + R_{t-1})}{(1 + \pi_{i,t})(1 + y_{i,t})}\left(\frac{B_{i,t-1}}{P_{i,t-1}Y_{i,t-1}}\right) + \frac{(G_{i,t} - t_i^c C_{i,t})}{Y_{i,t}} - (1 - \nu)t_i^l - \frac{\nu(\rho - \delta + \delta t_i^k)t_i^k}{\rho} \quad (30)$$

Solving this equation (30) forwards, with $\lim_{t\to\infty} B_{i,t}=0$ (we suppose a no-Ponzi-game, and the satisfaction of the intertemporal budgetary constraint), we can obtain[7]:

$$\left(\frac{B_{i,t}}{P_{i,t}Y_{i,t}}\right) = \beta E_t\{\sum_{n=0}^{\infty} \beta^n \frac{(1 + y_{i,t+n+1}) \dots (1 + y_{i,t+1})C_{i,t}}{C_{i,t+n+1}}$$
$$[(1 - \nu)t_i^l + \frac{\nu(\rho - \delta + \delta t_i^k)t_i^k}{\rho} - \frac{G_{i,t+n+1}}{Y_{i,t+n+1}} + t_i^c \frac{C_{i,t+n+1}}{Y_{i,t+n+1}}]\} \quad (31)$$

Therefore, if we suppose that private consumption increases in the long run at the same pace as GDP [see equation (A7)], using equations (A7) and (A10) in Appendix A, the steady state long run value for the real debt to GDP ratio in the country (i) ($b_i$) is as follows[8]:

$$b_i = \frac{\beta}{(1 - \beta)}\left[(1 - \nu)t_i^l + \frac{\nu(\rho - \delta + \delta t_i^k)}{\rho}t_i^k - \frac{G_i}{Y_i} + t_i^c \frac{C_i}{Y_i}\right] = 0 \quad (32)$$

Appendix A details the expression of the short run and long run values of all components of global demand of our macro-economic model.

Besides, log-linearizing equation (30), as $(\pi_{i,t})$ $(y_{i,t})$ and $(R_t)$ are small, using equation (8), in variations from its long term equilibrium value, we obtain:

$$b_{i,t} = (1 + R - \pi_i - y_i)b_{i,t-1} + (R_{t-1} - \pi_{i,t} - y_{i,t}) + \frac{(G_i - t_i^c C_i)}{b_i Y_i}(c_{i,t} - y_{i,t}) \quad (33)$$

With ($b_{i,t}$): deviation of the real debt to GDP ratio ($\frac{B_{i,t}}{P_{i,t}Y_{i,t}}$) in comparison with its long run equilibrium value ($b_i$).

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[7] Equations (5) implies: $\frac{E_t[(1+\pi_{i,t+n+1})\dots(1+\pi_{i,t+1})]}{E_t[(1+R_{t+n})\dots(1+R_t)]} = \frac{\beta^{n+1}C_{i,t}}{E_t(C_{i,t+n+1})}$.

[8] $(\frac{G_i}{Y_i} - t_i^c \frac{C_i}{Y_i}) = \frac{[\rho(1-\nu)t_i^l + (\rho - \delta + \delta t_i^k)\nu t_i^k]}{\rho}$ according to equations (A7) and (A10) in Appendix A.

Therefore, as: $(G_i > t_i^c C_i)$ for plausible values of our parameters (see Appendix A; private consumption is not the only fiscal base), we must have $(c_{i,t} = y_{i,t})$ in order to avoid an outbidding of the public indebtedness level.

Regarding the monetary policy of the common central bank, we suppose that the nominal 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 (h). So, the nominal interest rate is fixed as follows:

$$R_T = hR_{T-1} + (1-h)[R + 0.5(\pi_T - \pi^{opt}) + 0.5(y_T - y^{opt})] \quad (34)$$

With: (R): Equilibrium or natural interest rate, which corresponds to the long term rate of return if prices and wages were fully flexible. Therefore, we can estimate that it corresponds to the natural or potential economic growth in the monetary union ($R = y^{opt}$).
($\pi^{opt}$): targeted inflation rate.

Therefore, equation (34) implies the following common nominal interest rate:

$$R_T = hR_{T-1} + 0.5(1-h)R + 0.5(1-h)[\omega_i\pi_{i,T} + (1-\omega_i)\pi_{j,T} + \omega_i y_{i,T} + (1-\omega_i)y_{j,T}] - 0.5(1-h)\pi^{opt} \quad (35)$$

Where ($\omega_i$) is the relative share of the country (i) in the monetary union.

## 3.4. The global equilibrium

We are now going to derive the equilibrium on the goods market regarding global demand. Clearing on the goods market, equality between supply and demand of goods and services, in the country (i) in period (T) requires:

$$Y_{i,T} = C_{i,T} + G_{i,T} + (INV_{ii,T} + INV_{ji,T}) + (X_{i,T} - M_{i,T}) \quad (36)$$

With ($X_i$): exports of the country (i) and ($M_i$): imports of the country (i).

So, by combining equations (3), (10), (12), (16), (17), (18), (29) and (36), we obtain [see equation (A6) in Appendix A]:

$$(X_{i,T} - M_{i,T}) = \frac{\delta(1-t_i^k)}{(t_j^k - t_i^k)}(K_{ii,T} + K_{ji,T}) + \frac{\delta(1-t_j^k)}{(t_j^k - t_i^k)}(K_{jj,T} + K_{ij,T}) \quad (37)$$

Therefore, the global equilibrium and equation (37) allow to define the commercial balance of the country (i). If its capital taxation rate is weaker than in the rest of the monetary union ($t_i^k < t_j^k$), the country (i) is net exporter of goods and services, whereas if its capital taxation rate is higher, the country (i) is net importer.

Besides, in logarithms and in variations, equation (36) implies:

$$y_{i,T} = \frac{C_i}{Y_i}c_{i,T} + \frac{G_i}{Y_i}g_{i,T} + \frac{(INV_{ii} + INV_{ji})}{Y_i}inv_{i,T} + \frac{(X_i - M_i)}{Y_i}(x_{i,T} - m_{i,T}) \quad (38)$$

Where the relative shares of the components of global demand are mentioned in Appendix A.

The share of investment in capital ($\delta$) and footnote 8 imply the following constant relative share of investment in GDP:

$$\frac{(INV_{ii,T} + INV_{ji,T})}{Y_{i,T}} = \frac{INV_{.i,T}}{K_{.i,T}}\frac{K_{.i,T}}{Y_{i,T}} = \frac{\delta\nu(1-t_i^k)}{\rho} \quad (39)$$

So, using also equations (33) and (38), we have:

$$inv_{.i,T} = y_{i,T} = k_{.i,T} = c_{i,T} = g_{i,T} = (x_{i,T} - m_{i,T}) \quad (40)$$

Therefore, all economic variables and factors of global demand are growing at the same pace, in order to avoid an outbidding of the public indebtedness level, and to allow a

stable dynamic economic growth. Economic activity increases at the exogenous pace of capital accumulation in a given economy.

Furthermore, according to equations (11) and (40), this economic growth of global demand is perfectly anticipated: $E_t(k_{i,,t+1}) = k_{i,,t}$ (41).

In this context, according to equations (6), (28) and (40), we obtain:

$$R_T = E_T(\pi_{i,T+1}) = \frac{1}{\beta}\pi_{i,T} = \frac{1}{\beta}\pi_{j,T} \qquad (42)$$

Therefore, the optimal nominal interest rate should increase in proportion to the inflation rates, which should be equalized in all member countries of the monetary union.

Besides, according to equation (34), in the long run, the average inflation rate ($\pi = \pi^{opt}$) and economic growth ($y = y^{opt}$) are at their optimal levels. So, equations (35) and (42) also implies the following current nominal interest rate:

$$R_T = \frac{h}{[1-0.5(1-h)\beta]}R_{T-1} + \frac{0.5(1-h)(1-\beta)}{\beta[1-0.5(1-h)\beta]}\pi^{opt} + \frac{0.5(1-h)}{[1-0.5(1-h)\beta]}[\omega_i y_{i,T} + (1-\omega_i)y_{j,T}] \qquad (43)$$

So, the current nominal interest rate is an increasing function of its previous level (interest rate smoothing). Furthermore, it also increases with the optimal targeted inflation rate, and with economic growth in the monetary union.

Finally, solving forwards equation (33), with (42), ($b_i$=0) and ($y = y^{opt} = R$), we obtain the following variation of the real public debt to GDP ratio in the country (i):

$$b_{i,T} = \sum_{k=0}^{\infty} \frac{1}{(1+R-\pi_i-y_i)^{k+1}} E_t(y_{i,T+k+1} - R_{T+k} + \pi_{i,T+k+1}) = \sum_{k=0}^{\infty} \frac{\beta}{[\beta(1-y_i)+(1-\beta)\pi_i]^{k+1}} E_t(y_{i,T+k+1}) \qquad (44)$$

Therefore, the real public debt to GDP ratio is growing in proportion of future anticipated real economic activity growth rates.

## 3.5. Calibration of the parameters

The EUTAX model of Sorensen (2001) calibrates the share of capital in GDP at ($\nu = 0.33$), whereas Mendoza (2001) or Mendoza and Tesar (2005) calibrate this share of capital at (ν=0.36). In conformity with empirical data and with economic studies, we can then calibrate the share of capital in GDP at (ν=0.33). In the same way, according to empirical data, the world after tax net return of capital can be calibrated around (ρ=12%). Mendoza and Tesar (2005) calibrate the depreciation rate of capital at (δ=0.02); we will retain a value close to one mentioned in most economic studies: (δ=0.025).

Furthermore, De Mooij and Ederveen (2003) provide a meta-analysis wondering about the differentials in the results obtained by economic surveys on the sensibility of investment to capital taxation rates. With a large data base, they conclude that capital flows to tax havens and by non-manufacturing firms (which may contain much more financial capital) are probably more responsive to taxes than real capital, which is itself more responsive to taxes than mergers and acquisitions. The authors find huge differentials in the results of economic surveys; however, the mean value of the tax rate elasticity in the literature is around -0.7%,

i.e. a 1% reduction in the host-country tax rate raises foreign direct investment in that country by about 0.7%. Hines (1999) also underlines empirically that the fiscal context influences investment location. He finds an elasticity of (-0.6%): he assumes that a 1% point increase in the foreign tax rate reduces US investment in a country by 0.6%.

Finally, in conformity with the implicit tax rates mentioned by the European Commission (2018), we will consider the following average taxation rates regarding capital ($\tau_k = 0.3$), labor ($\tau_l = 0.35$) and consumption ($\tau_c = 0.2$).

## 4. Theoretical factors influencing the public debt level

In the framework of the previous theoretical model, we can now define the economic and fiscal factors liable to influence the level of the public debt in a member country of a monetary union (see Appendix B).

### 4.1. Economic factors

According to equation (B2) in Appendix B, if the capitalization of the country (i) increases in the period (t) in comparison with its previous value in the period (t-1) ($K_{.i,t} > K_{.i,t-1}$), it increases economic growth in period (t) in the country (i), the denominator of the public debt to GDP ratio, and therefore, it reduces this ratio. The weight of the reimbursement of the former public debt can be lightened. A higher expected capitalization and future anticipated economic growth also reduces the weight of the current public debt, provided the preference of households for public goods consumption is sufficiently strong ($\alpha_g > \alpha_c t_i^c$). Indeed, according to equations (B3) and (B4) in Appendix B, we obtain:

$$\frac{\partial\left(\frac{B_{i,T}}{P_{i,T}Y_{i,T}}\right)}{\partial\left[\frac{E_T\left(K_{ih,T+1}\right)-K_{ih,T}}{\left(K_{ii,T}+K_{ji,T}\right)}\right]} = -\frac{\nu\left(\alpha_g-\alpha_c t_i^c\right)\left(1-t_h^k\right)}{\rho\left(\alpha_c+\alpha_g\right)} \qquad h = i \text{ or } j \qquad (45)$$

$$\frac{\partial\left(\frac{B_{i,T}}{P_{i,T}Y_{i,T}}\right)}{\partial\left(\frac{K_{ih,T}}{K_{ii,T}+K_{ji,T}}\right)} = \frac{\nu\left(\alpha_g-\alpha_c t_i^c\right)\left(1-t_h^k\right)\left(\rho-2\delta+\delta t_h^k\right)}{\rho\left(\alpha_c+\alpha_g\right)} \qquad h = i \text{ or } j \qquad (46)$$

So, according to the basic calibration of the parameters of our model, if ($\alpha_g = \alpha_c$), equation (45) implies: $\partial\left(\frac{B_{i,T}}{P_{i,T}Y_{i,T}}\right) \sim -0.33\ \partial\left[\frac{E_T\left(K_{ih,T+1}\right)-K_{ih,T}}{\left(K_{ii,T}+K_{ji,T}\right)}\right]$.

However, according to equation (46), the situation is different if we do not consider the variation but the absolute value of the capital stock in a given country of the monetary union. Indeed, a high level of sparing and of national or foreign investment of households living in the country (i) increases the stock of capital in the monetary union, but it also reduces the resources available to finance public expenditure. So, if households prefer private consumption, more resources are expected to be devoted to private investment, and the public debt can decrease as there is less public expenditure to be financed. On the contrary, if households have a sufficiently high preference for public consumption ($\alpha_g > \alpha_c t_i^c$), the public debt to GDP ratio must increase in order to finance the level of public expenditure desired by the population. Nevertheless, this effect would be theoretically quite limited, as

with the basic calibration of the parameters of our model, if ($\alpha_g = \alpha_c$), equation (46) implies: $\partial(\frac{B_{i,T}}{P_{i,T}Y_{i,T}}) = 0.06\ \partial(\frac{K_{ih,T}}{K_{ii,T}+K_{ji,T}})$.

Besides, according to equations (B5) and (B6) in Appendix B, the derivatives of the public debt to GDP ratio in function of the world capital rate of return (ρ) or of the share of capital in the production function (ν) are not clear cut. However, if the depreciation rate of capital increases, the public debt to GDP ratio tends to be higher. Private investment must be designed to increase the capital stock, but also to replace the depreciated previous capital stock at a higher pace. So, less financial resources are available to finance public expenditure, and the public debt increases. Indeed, according to equation (B7) in Appendix B, we have:

$$\frac{\partial(\frac{B_{i,T}}{P_{i,T}Y_{i,T}})}{\partial\delta} \text{ ì } \frac{\nu(1-t_i^k)[\alpha_c(t_i^k+2\delta t_i^c)+\alpha_c t_i^k t_i^c(1-\delta)-\alpha_g\delta(2-t_i^k)]}{\rho(\alpha_c+\alpha_g)} > 0 \qquad (47)$$

According to the basic calibration of the parameters of our model, if ($\alpha_g = \alpha_c$), this would imply: $\partial(\frac{B_{i,T}}{P_{i,T}Y_{i,T}})$~0.9 ($\partial\delta$).

Furthermore, if the preference of households for public goods and services increases in comparison with the preference for private consumption, the public debt to GDP ratio should also increase, in order to finance a higher level of public expenditure and the public goods and services desired by the population. Indeed, according to equation (B8) in Appendix B, we have:

$$\frac{\partial(\frac{B_{i,T}}{P_{i,T}Y_{i,T}})}{\partial\left(\frac{\alpha_g}{\alpha_c}\right)} - \frac{(1+t_i^c)(\rho-2\nu\delta+2\nu\delta t_i^k)}{\rho}\left(\frac{\alpha_c}{\alpha_c+\alpha_g}\right)^2 > 0 \qquad (48)$$

According to the basic calibration of the parameters of our model, if ($\alpha_g = \alpha_c$), this would imply: $\partial(\frac{B_{i,T}}{P_{i,T}Y_{i,T}})$~0.27 $\partial(\frac{\alpha_g}{\alpha_c})$.

## 4.2. Capital taxation rates

Beyond the economic factors influencing the public debt level mentioned in the previous section 4.1, obviously, there are also fiscal factors influencing the debt to GDP ratio.

First, according to equations (B11) and (B12) in Appendix B, a higher capital taxation rate increases fiscal resources and can contribute to reduce the debt to GDP ratio. However, because of tax evasion, if the capital taxation rate is then higher than in the other member countries of the monetary union, the fiscal base can be shortened, and the public indebtedness level can then increase. Indeed, we obtain:

$$\frac{\partial\left(\frac{B_{i,T}}{P_{i,T}Y_{i,T}}\right)}{\partial t_i^k} \rightarrow -\frac{\nu}{\rho\left(1+\frac{\alpha_g}{\alpha_c}\right)}\left[\rho-\delta+2\delta t_i^k+2\delta t_i^c+\frac{\alpha_g}{\alpha_c}(\rho-3\delta+2\delta t_i^k)\right] \qquad (49)$$

$$\frac{\partial\left(\frac{B_{i,T}}{P_{i,T}Y_{i,T}}\right)}{\partial(t_i^k-t_j^k)} \rightarrow \frac{\nu(\alpha_g-\alpha_c t_i^c)(\rho-3\delta+2\delta t_j^k)}{\rho(\alpha_c+\alpha_g)}\frac{K_{ij,T}}{(K_{ii,T}+K_{ji,T})} \qquad (50)$$

According to the basic calibration of the parameters of our model, if ($\alpha_g = \alpha_c$), equation (49) implies that on average, a 1% increase of the capital taxation rate would

decrease the public debt to GDP ratio by around (-0.25%). However, a higher capital taxation rate increases fiscal resources and reduces all the more the public debt level as the capital share in the production function (ν), as the world average capital return (ρ), and as the capital and consumption taxation rates ($t_i^k$ and $t_i^c$) are high. On the contrary, a higher capital taxation rate would be less efficient in order to reduce the public indebtedness level if the relative preference for public goods and services ($\alpha_g/\alpha_c$) or if the depreciation rate of capital ($\delta$) are high. Besides, according to equation (B11) in Appendix B, a higher capital taxation rate would also be less efficient to reduce the public indebtedness level if households from the country (i) increase their national or foreign sparing and their investment in capital in one country of the monetary union, so if capitalization and economic growth is higher.

Nevertheless, equation (50) also underlines an important effect of the financial openness in a monetary union. Indeed, if the capital taxation rate is higher in the country (i) than in the rest of the monetary union, fiscal evasion towards the rest of the monetary union reduces the fiscal base in this country (i). So, it contributes to increase the public debt to GDP ratio in this country, provided the preference for public goods and services is sufficiently high ($\alpha_g > \alpha_c t_i^c$). However, this effect remains quite moderate. Indeed, it depends on the foreign investment in capital of households from the country (i) in the rest of the monetary union ($K_{ij,T}$); with the basic calibration of our model, if ($\alpha_g = \alpha_c$), we obtain: $\partial\left(\frac{B_{i,T}}{P_{i,T}Y_{i,T}}\right) \sim 0.07 \frac{K_{ij,T}}{(K_{ii,T}+K_{ji,T})} \partial(t_i^k - t_j^k)$.

## 4.3. Labor and consumption taxation rates

Because of tax competition and tax evasion, increasing the consumption or labor taxation rates is a more efficient economic policy, in order to collect fiscal resources and to decrease the public debt level, than increasing the capital taxation rate. Indeed, according to equation (B9) in Appendix B, we obtain:

$$\frac{\partial\left(\frac{B_{i,T}}{P_{i,T}Y_{i,T}}\right)}{\partial t_i^c} \to -\frac{\left(\rho - 2\nu\delta + 2\nu\delta t_i^k\right)}{\rho\left(1+\frac{\alpha_g}{\alpha_c}\right)} < 0 \qquad (51)$$

According to the basic calibration of the parameters of our model, if ($\alpha_g = \alpha_c$), equation (51) implies that on average, a 1% increase of the consumption taxation rate would decrease the public debt to GDP ratio by around (-0.45%). However, a higher consumption taxation rate increases fiscal resources and reduces all the more the public debt level as the average world capital return (ρ), and as the capital taxation rate ($t_i^k$) are high. On the contrary, a higher consumption taxation rate would be less efficient in order to reduce the public indebtedness if the share of capital in the production function (ν), if the relative preference for public goods and services ($\alpha_g/\alpha_c$) or if the depreciation rate of capital ($\delta$) are high.

Besides, according to equation (B9) in Appendix B, a higher consumption taxation rate would be more efficient in order to reduce the public indebtedness level if the national country (i) is net capital exporter in the monetary union ($K_{ij,T} > K_{ji,T}$). On the contrary, it would be less efficient to reduce the public indebtedness level if households from the country (i) increase their national or foreign sparing and their investment in capital in one country of the monetary union [$E_T\left(K_{ih,T+1}\right) > K_{ih,T}$], so if capitalization and economic growth is higher.

Furthermore, according to equation (B10) in Appendix B, we obtain:

$$\frac{\partial(\frac{B_{i,T}}{P_{i,T}Y_{i,T}})}{\partial t_i^l} = -(1-\nu) < 0 \qquad (52)$$

So, with the basic calibration of the parameters of our model, if ($\alpha_g = \alpha_c$), equation (52) implies that on average, a 1% increase of the labor taxation rate would decrease the public debt to GDP ratio by around (-0.67%). Therefore, it would be the most efficient economic policy to reduce the weight of the public indebtedness. Besides, a higher labor taxation rate increases fiscal resources and would be all the more efficient in order to reduce the public debt level as the labor share in the production function (1- $\nu$) is high.

## 5. Empirical results

This section will now confront the theoretical results of our model with empirical data of the European Economic and Monetary Union (EMU). To this goal, for the year 1970, we will consider data regarding five founding members of the European Union (Belgium, Germany, France, Italy and the Netherlands; we have excluded Luxembourg), as well as for the three countries joining the European Union in 1973 (Denmark, Ireland and the United-Kingdom). For 1986, we have added data for Greece, that joined the Union in 1981, as well as for Spain and for Portugal, that joined the Union in 1986.

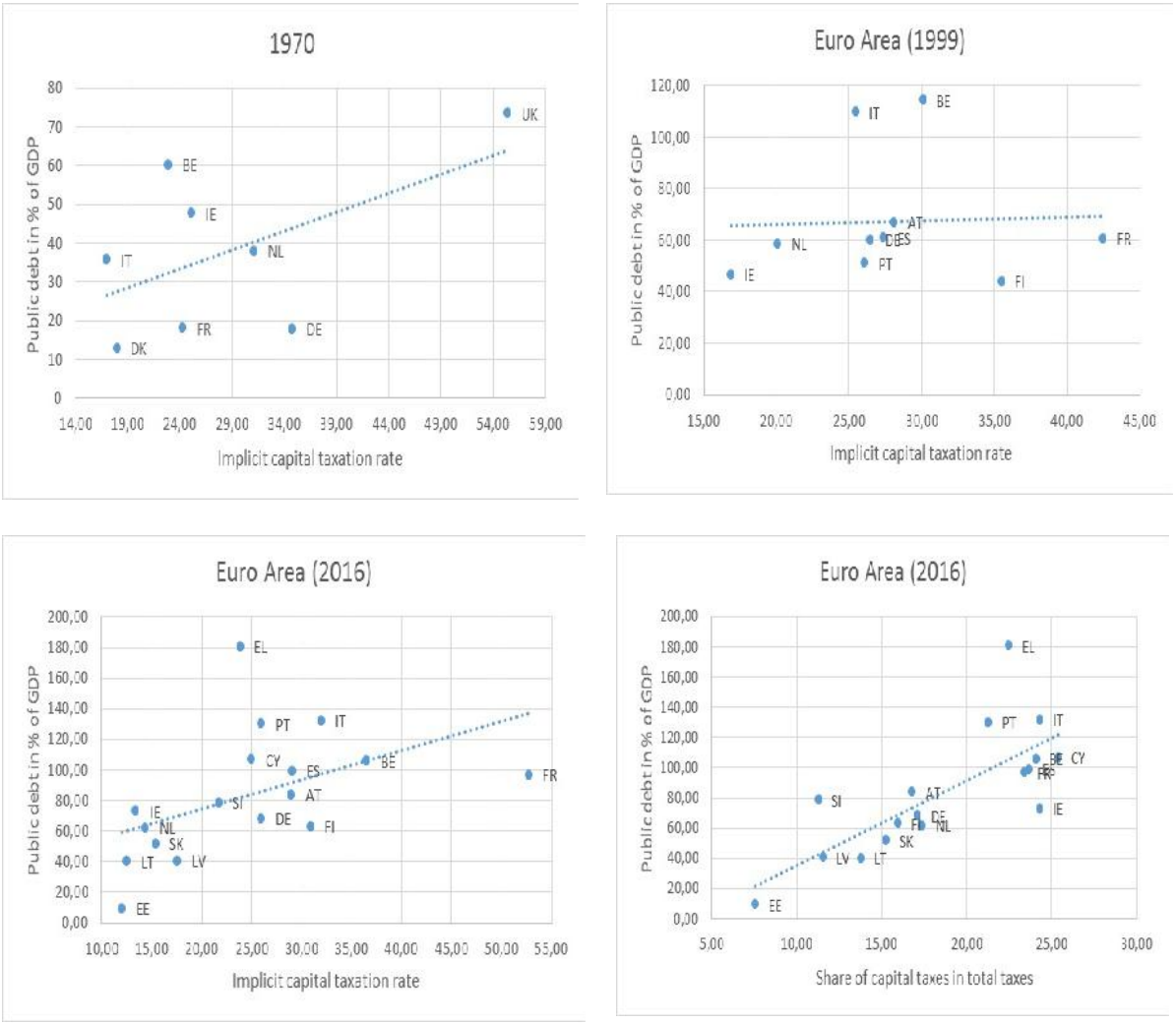
However, the theoretical modelling of the former sections of this paper concerns fiscal interdependencies between the member countries of a monetary union, which share the same interest rate. So, in 1999, we will consider ten among the eleven countries of the Euro Area: Belgium, Germany, Ireland, Spain, France, Italy, the Netherlands, Austria, Portugal and Finland (we have excluded Luxembourg). Afterwards, other countries have integrated the Euro Area: Greece (2001), Slovenia (2007), Cyprus (2008) (we have excluded Malta that also joined in 2008), Slovakia (2009) Estonia (2011), Latvia (2014), and Lithuania (2015). Therefore, the empirical part of the paper will mostly concern these seventeen main member countries of the Euro Area.

### 5.1. Public debt levels and capital taxation rates

In the long run, empirical data seem to show an increasing relation between the implicit capital taxation rate and the public debt level in the member countries of the Euro Area. This result already seemed to be verified in 1970 for the first members of the European Union; it was valid in 1999 when the Euro Area was created, as well as in 2016 (see Figure 1). Besides, for these last dates, the increasing relation would also be valid if all member countries of the European Union were considered. Figure 1 shows that this relation was not obvious in 1999, when the EMU was created. However, in 2016, Estonia (12%) or Lithuania (12.5%) were the countries with the weakest implicit capital taxation rates and also with the lowest public debt levels (respectively 9.4% and 40.1% of GDP), whereas on the contrary, France was the country with the highest implicit capital taxation rate (52.8%), and this country also had a very high public debt level (96.6% of GDP).

We can also note the empirical increasing relation between capital taxation rates and public debt levels by considering the relative share of capital taxes in total taxation. For example, in 2016, the share of capital taxes in total taxation was low in Estonia (7.6%), where the public debt level was also low (9.4% of GDP). On the contrary, this share was quite high in Italy (24.3%), in Portugal (21.3%) or in Greece (22.5%), where the public debt levels are the highest (respectively: 132%, 129.9% and 180.8% of GDP).

**Figure 1**: Capital taxation rates and public debt levels in the Euro Area

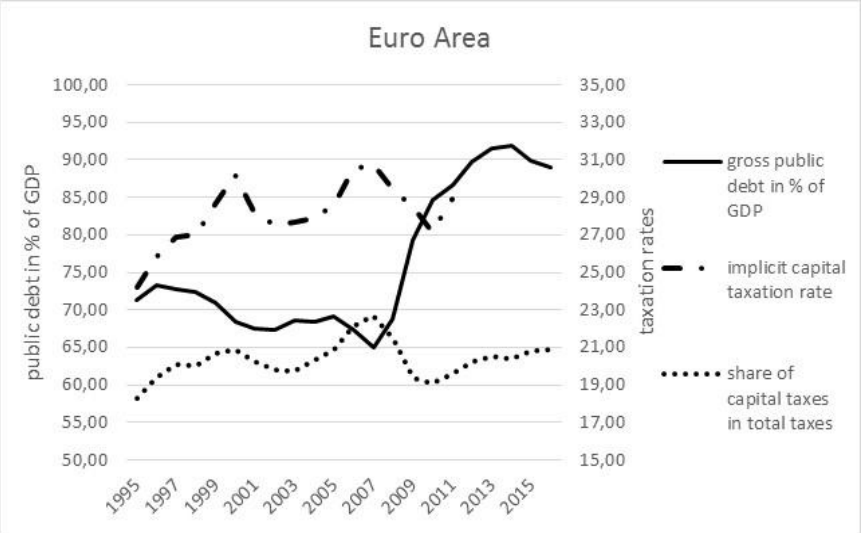



*Source: data of Eurostat and of the European Commission*

Therefore, empirical data in Figure 1 show that a policy of high capital taxation rates is not an efficient way to collect more fiscal resources and to decrease the public debt level. Only the less indebted European countries can afford to have low capital taxation rates. Nevertheless, highly indebted countries do not seem to succeed to solve their fiscal difficulties and their problems of excessive public indebtedness with the help of high capital taxation rates. Indeed, as mentioned by our theoretical model, to maintain high capital taxation rates is weakly efficient, in order to collect fiscal resources, particularly in a framework of tax competition.

Furthermore, historical data related to the global Euro Area show that the relation between capital taxation rates and public debt levels is quite ambiguous. Indeed, the average public debt level very strongly increased in the Euro Area after the economic and financial crisis, from 65% in 2007 to 91.9% in 2014. However, during the same period, the implicit capital taxation rate decreased from 30.8% in 2007 to 27.2% in 2010, before beginning to increase again (see Figure 2). Besides, the average share of capital taxes in total taxation in the Euro Area varied between 19% and 23% since 1995, but it doesn't seem to be clearly related to the global public debt level.

**Figure 2**: Average public debt level and capital taxation in the Euro Area




What was the historical evolution of both economic variables in some specific member countries of the Euro Area? In Germany, the public debt level increased from 20% in 1970 to 80.9% of GDP in 2010. In this context, we can observe than the implicit capital taxation rate very strongly decreased, from 47.4% in 1980 to 20% in 2010 (also a consequence of the reunification). However, between 1995 and 2016, the implicit capital taxation rate has been stabilized between 20% and 25%, despite variations in the public indebtedness (see Appendix C). In Spain, the implicit capital taxation rate increased from 20.7% to 42.9% between 1995 and 2007, whereas the public debt level decreased from 65.6% in 1996 to 35.6% of GDP in 2007. On the contrary, the implicit capital taxation rate decreased from 42.9% in 2007 to 25.8% in 2011, whereas the public debt level increased from 35.6% in 2007 to 100.4% of GDP in 2014. The hypothesis of a decreasing relation can therefore be validated. In the same way, in Belgium, the implicit capital taxation rate decreased from 34.1% to 24% between 1979 and 1992, whereas the public debt level very strongly increased from 57.9% in 1973 to 134.4% of GDP in 1993. On the contrary, the implicit capital taxation rate increased from 24% in 1992 to 31.9% in 2006, whereas the public debt level then decreased from 134.4% in 1993 to 87% of GDP in 2007. However, since 2007, the relation is much more ambiguous.

Nevertheless, in France, we can only observe this decreasing relation between the capital taxation rate and the public indebtedness level between 1982 and 1995. Indeed, during this period, the implicit capital taxation rate decreased from 45.8% to 36.5%, whereas the public debt level increased from 25.5% to 55.8% of GDP. However, since 1995, the relation is mainly increasing between both economic variables. According to our theoretical model, this could be explained by the excessive level of the capital taxation rate in France in comparison with its partner countries in the monetary union. Indeed, the average implicit capital taxation rate increased from 36.5% in 1995 to 52.8% in 2016 in France, and thus, it was much beyond the average capital taxation rate in the Euro Area (around 29%). Therefore, this excessive capital taxation rate could contribute to explain the increase of the public debt level in France, from 55.8% in 1995 to 96.6% of GDP in 2016.

In Italy, there is mainly a correlation between the increase in the capital taxation rate and in the public debt level since the 1970's. In the Netherlands, the public debt level was reduced from 74.2% in 1990 to 51.7% of GDP in 2000; at the same time, the implicit capital taxation rate decreased from around 29.7% in 1988 to 18.8% in 2000, and the relation was increasing. However, between 2000 and 2014, the public debt level increased again from 51.7% to 68% of GDP, whereas the implicit capital taxation rate continued to decrease from

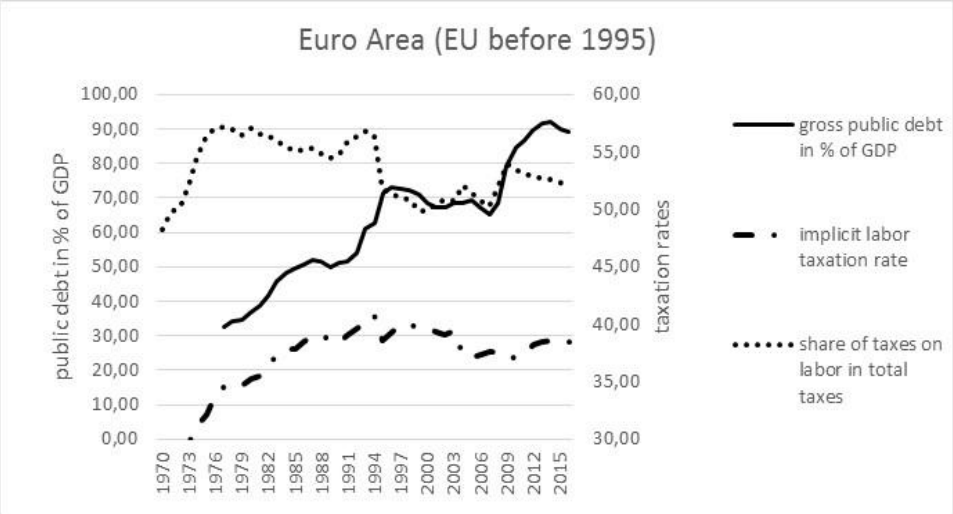
18.8% to 8.8% in 2011. Therefore, empirical data seem to show an ambiguous relation between the capital taxation rate and the public debt level. As mentioned by our theoretical model, capital taxation would then be quite inefficient to collect more fiscal resources and to decrease the public debt level, in the framework of a monetary union.

## 5.2. Public debt levels and labor taxation rates

Our theoretical model also shows that only when its labor taxation rate is weak can a country afford to have a high public indebtedness level (decreasing relation). Is this result validated by empirical data?

The average public debt level increased in the Euro Area since the 1970's. So, the implicit labor taxation rate in the European Union slightly increased from around 30% in 1973 to 38.4% in 2016, in order to collect enough fiscal resources to finance this public debt (see Figure 3). However, since 1995, the implicit labor taxation rate is quite stable (around 40%) in the member countries of the Euro Area, despite the continuing growth of the public indebtedness level, which always necessitates more fiscal resources. Besides, the average share of labor taxes in total taxation was around 55% in the European Union before 1995, whereas it has been limited to about 50% after 1995 in the Euro Area. Therefore, this could be coherent with the fact that in a monetary union, high public debt levels can only be sustained in countries where labor taxation rates are restricted.

**Figure 3**: Average public debt level and labor taxation in the Euro Area




If we look at historical data for specific European countries (see Appendix C), the following results can be observed. In Germany, the public debt increased from 38.9% in 1991 to 80.9% of GDP in 2010. The implicit labor taxation rate then very slightly decreased from 39.8% to 36.9% between 1991 and 2010, whereas the share of labor taxes in total taxation decreased from around 65% to 55% during the same period. In France, the public debt level increased from 20% in 1980 to 96.6% of GDP in 2016. The implicit labor taxation rate was then reduced from 44.1% in 1994 to 38.5% in 2010, whereas the share of labor taxes in total taxation decreased from 56.7% to 52.8%.

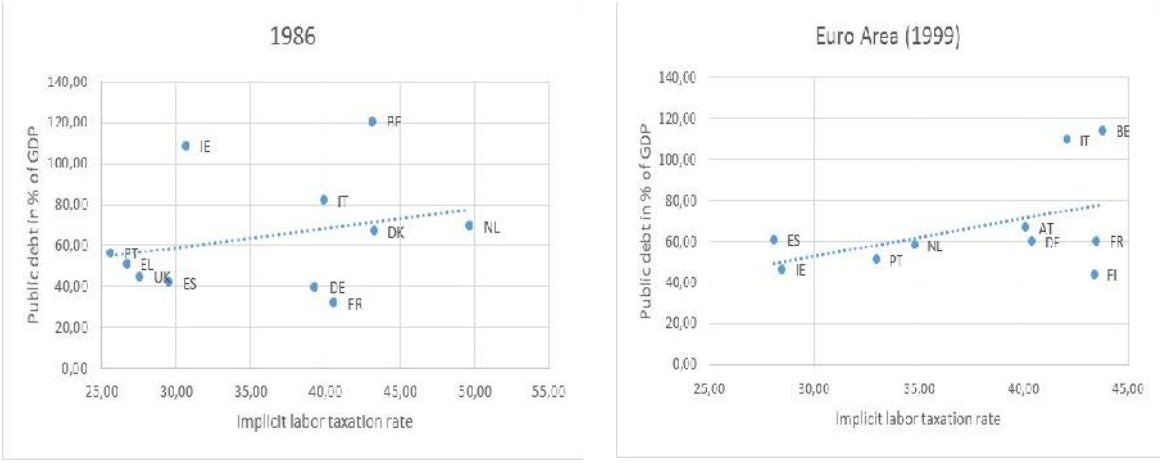
In Italy or in Belgium, the public indebtedness has strongly increased, and in order to finance this public debt, the implicit labor taxation rate has also increased in the 1970's and in the 1980's. However, the implicit labor taxation rate is stabilized around 43% in Italy as well as in Belgium, since the 1990's. In Spain, since the 1980's, the implicit labor taxation rate is

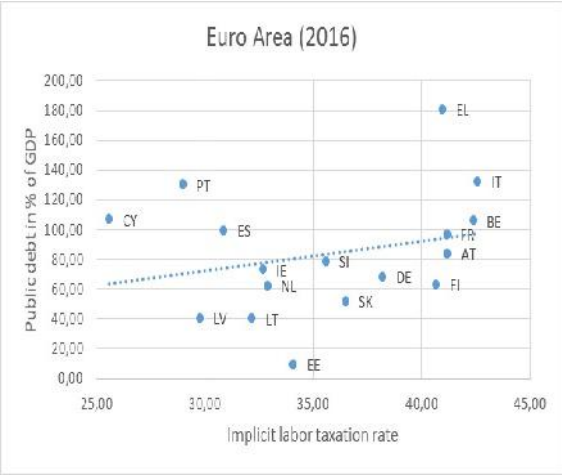
also quite stable, around 30%, even if the public debt level strongly increased from 24.5% in 1982 to 100.4% of GDP in 2014. Finally, in the Netherlands, after a huge decrease of the implicit labor taxation rate, from 52.3% in 1991 to 31.4% in 2000, this rate was afterwards stabilized around 32%, despite variations in the public debt level. Therefore, since the creation of the EMU, variations of the labor taxation rates in the member countries seem empirically quite moderate and negligible, and they also seem relatively independent from variations of the public debt levels.

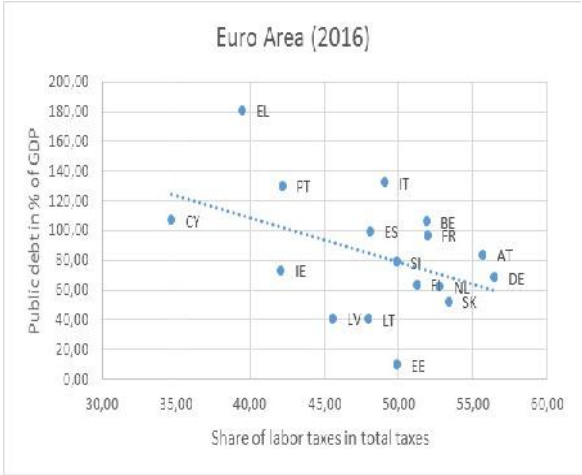
Regarding the relative situations of the European countries at a specific date, the link between the implicit labor taxation rate and the public debt level would be mostly positive (see Figure 4). This result was already verified in 1986 for the first member countries of the European Union, and it was still verified in 1999 and in 2016 in the Euro Area. Indeed, in 1999, at the creation of the EMU, implicit labor taxation rates were weak in Spain (28.1%) and in Ireland (28.5%), where public debt levels were also weak (respectively 60.9% and 46.6% of GDP). On the contrary, implicit labor taxation rates were high in Italy (42.1%) and in Belgium (43.8%), where the public debt levels were also high (respectively 109.7% and 114.4% of GDP). In the same way, in 2016, Latvia (29.8%), Lithuania (32.2%) or Estonia (34.1%) were countries with weak implicit labor taxation rates and also with the lowest public debt levels (respectively 40.5%, 40.1% and 9.4% of GDP). On the contrary, in 2016, Greece (41%), Italy (42.6%) and Belgium (42.4%) were countries with high implicit labor taxation rates, and also with the highest public debt levels (respectively 180.8%, 132% and 105.9% of GDP). Nevertheless, we can give the following interpretation to this apparent positive link.

Only initially weakly indebted European countries can afford to have weaker labor taxation rates, as the weight of the reimbursement of their public debt is more limited, and as they need less fiscal resources. Indeed, as mentioned by our theoretical model, weak labor taxation rates imply a risk to increase the public debt level. That's why there seems to be a decreasing relation between the relative share of labor taxes in total taxation and the public debt level (see Figure 4). Indeed, in 2016, the share of labor taxes in total taxation was low in Cyprus (34.7%) or in Greece (39.5%), where the public debt levels were high (respectively 106.6 and 180.8% of GDP). On the contrary, the share of labor taxes is total taxation was the highest in Austria (55.7%) or in Germany (56.5%), where the public debt levels were more limited (respectively: 83.6% and 68.2% of GDP).

**Figure 4**: Labor taxation rates and public debt levels in the Euro Area






*Source: data of Eurostat and of the European Commission*

To conclude, empirical data are not in contradiction with the theoretical result of our model. Weak labor taxation rates imply the risk to limit fiscal resources and to increase the public debt level. Therefore, only initially weakly indebted countries (Latvia, Lithuania or Estonia) could afford to have weak labor taxation rates. On the contrary, a high share of labor taxes in total taxation could have contributed to limit the public indebtedness level in other countries, for example in Austria or in Germany.

## 5.3. Public debt levels and consumption taxation rates

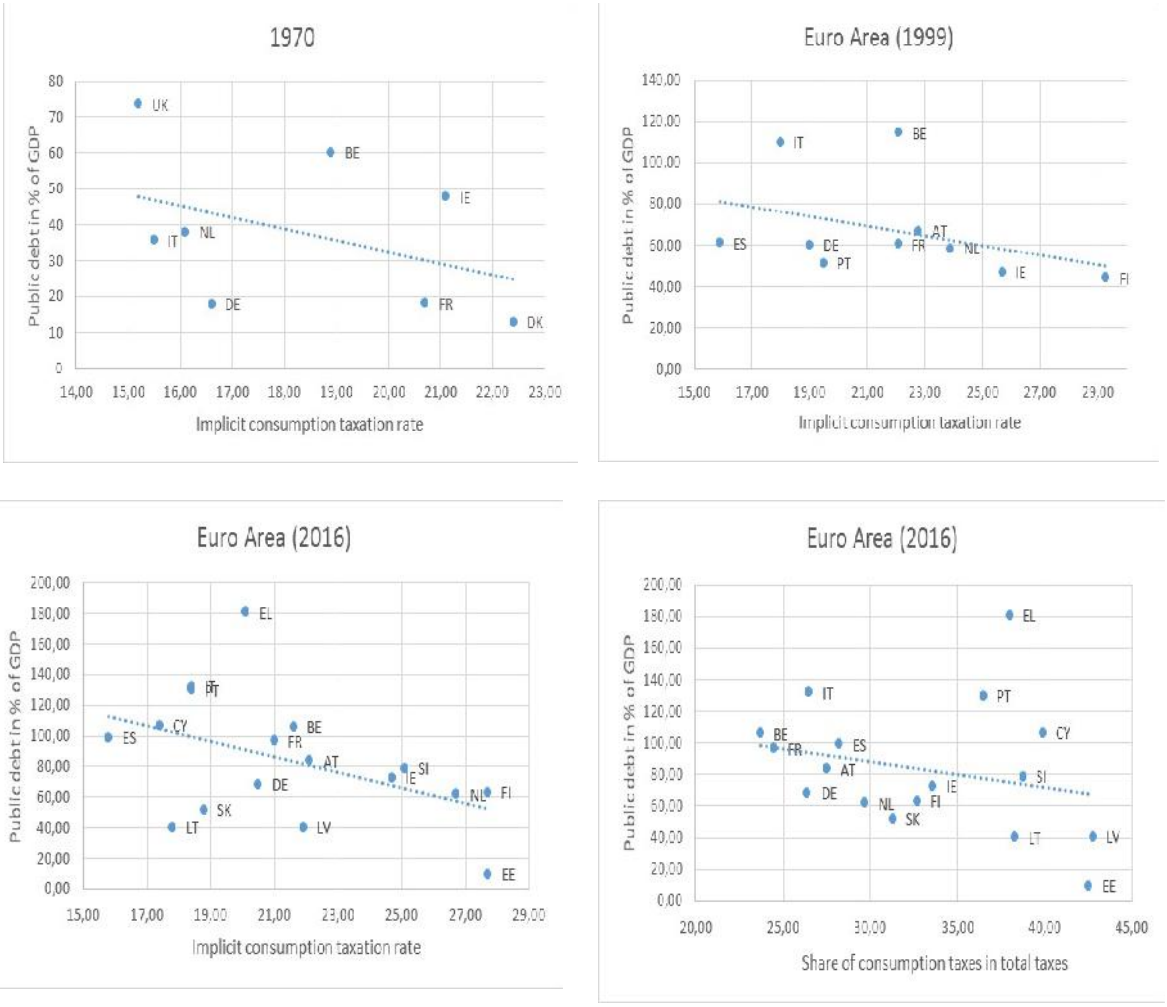
Empirical data show a decreasing relation between implicit consumption taxation rates and public debt levels in the member countries of the Euro Area. This result was already verified in 1970 for the first member countries of the European Union, and it was still verified in 1999 and in 2016 in the Euro Area (see Figure 5). We can mention that for these last dates, the result would also be valid if all member countries of the European Union were considered. Therefore, in conformity with our theoretical result, a weak consumption taxation rate implies the risk to have a higher public indebtedness level.

For example, in 1999, Finland was a country with a high implicit consumption taxation rate (29.3%) and a low public debt level (44.1% of GDP), whereas on the contrary, Italy was a country with a low implicit consumption taxation rate (18%) but a high public debt level (109.7% of GDP). In the same way, in 2016, Estonia (27.7%) or Finland (27.7%) were the countries with the highest implicit consumption taxation rates but with low public debt levels (respectively 9.4% and 63% of GDP), whereas on the contrary, Greece was a country with a moderate implicit consumption taxation rate (20.1%) but with a very high public debt level (180.8% of GDP). Besides, we can mention that this decreasing relation is also verified for the countries of the European Union which are not members of the Euro Area. For example, in 2016, in Denmark or in Sweden, implicit consumption rates were high whereas public debt levels were quite low.

We can also observe this decreasing relation by considering the relative share of consumption taxes in total taxation (see Figure 5). For example, in 2016, the share of consumption taxes in total taxation was low in Belgium (23.7%) or in Italy (26.5%), where the public debt levels were high (respectively 105.9% and 132% of GDP). On the contrary, the share of consumption taxes in total taxation was high in Estonia (42.5%), in Latvia

(42.8%) or in Lithuania (38.3%), where the public debt levels were weak (respectively: 9.4%, 40.5% and 40.1% of GDP).

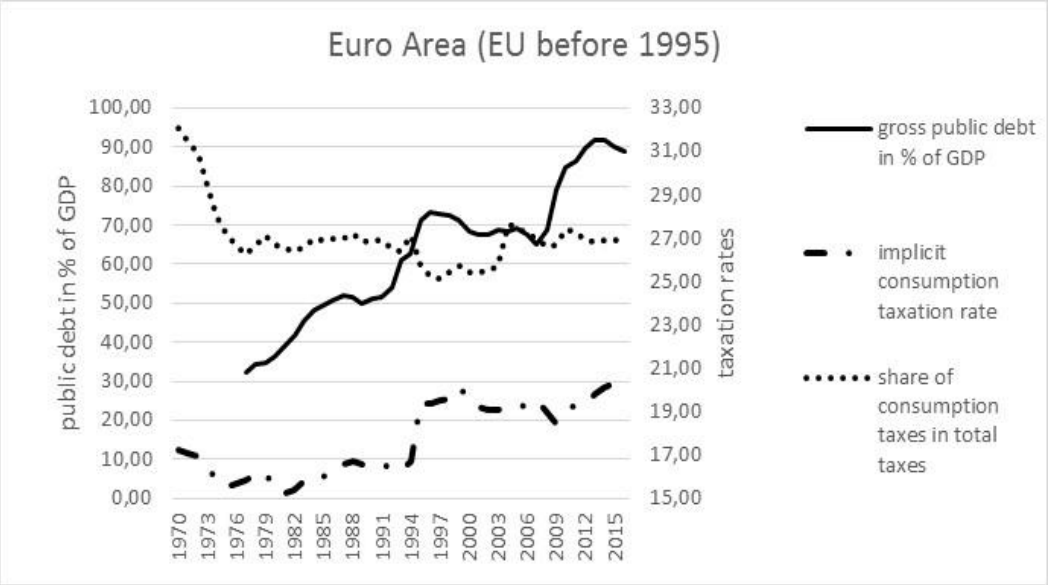
**Figure 5**: Consumption taxation rates and public debt levels in the Euro Area




*Source: data of Eurostat and of the European Commission*

Furthermore, Figure 6 shows that the average public debt level increased in the European Union (from 32% in 1977 to 65.3% of GDP in 1999), and afterwards in the Euro Area (until 91.9% of GDP in 2014). In this context, the implicit consumption taxation rate increased from 16% in 1985 until 20.5% in 2016, in order to finance this public debt. Nevertheless, the average implicit consumption taxation rate has been stabilized around 20% since 1999 and the creation of the EMU, despite the further increase of the average public debt level. Besides, the share of consumption taxes in total taxation decreased from 32.1% in 1970 to 27% in 2016 in the Euro Area.

**Figure 6**: Average public debt level and consumption taxation in the Euro Area




If we look at historical data for specific European countries (see Appendix C), the following evolutions can be observed. In Germany, the public debt increased from 17.8% in 1970 to 80.9% of GDP in 2010. Then, the implicit consumption taxation rate also increased from 15.4% in 1984 to 18.8% in 1995 in order to finance this public debt. However, this rate has been afterwards stabilized around 20%, despite the further increase of the public debt level. Besides, the share of consumption taxes in total taxation decreased from 29.8% in 1970 to around 24.3% in 1999. In France, the public debt level increased from 18% in 1970 to 96.6% of GDP in 2016. However, the implicit consumption taxation rate has been stabilized around 20% after 1999, despite the further increase of the public debt level. Besides, the share of consumption taxes in total taxation decreased from 36.5% in 1970 to 24.5% in 2016.

In Italy, the public debt level increased from 35.7% in 1970 to 132% of GDP in 2016. Here also, the implicit consumption tax rate has been stabilized around 18% since 1999, despite the further increase of the public debt. Besides, the share of consumption taxes in total taxation decreased from 38.3% in 1970 to 26.5% in 2016. In Belgium, the public debt reached a maximal level of 134.4% of GDP in 1994. However, it was afterwards reduced to 87% of GDP in 2007, whereas the implicit consumption taxation rate increased from 15.8% in 1992, before being stabilized around 21% after the creation of EMU in 1999. Besides, while the public debt level was increasing, the share of consumption taxes in total taxes decreased from 32.9% in 1970 to 23% in 1993. Finally, in the Netherlands, the public debt level was reduced from 74.2% in 1990 to 44.7% of GDP in 2006. At the same time, the implicit consumption taxation rate increased from 17.5% to 25.4%, and the share of consumption taxes in total taxes increased from 24.2% to 31.5%.

So, empirical data could validate the theoretical result that if the consumption taxation rate decreases, or at least if it is stabilized without increasing in a member country of a monetary union, this can contribute to limit the available fiscal resources, and this can increase the public indebtedness level. Relying on higher consumption taxes has empirically often been correlated with a better limitation of the weight of the public debt.

## 6. Conclusion

Our theoretical model shows that an increase of the labor taxation rate would be the most efficient economic policy to collect more fiscal resources and to reduce the public debt to GDP ratio; and all the more as the labor share in the production function is high. On the contrary, weak labor taxation rates would imply the risk to limit fiscal resources and to increase the public debt level. Therefore, empirical data show that only initially weakly indebted countries (Latvia, Lithuania or Estonia) can afford to have weak labor taxation rates. On the contrary, a high share of labor taxes in total taxation could have contributed to limit the public indebtedness level in other countries, for example in Austria or in Germany. However, since the creation of the EMU, variations of the labor taxation rates in the member countries seem empirically quite moderate and negligible, and they also seem relatively independent from variations of the public debt levels.

Furthermore, our model assumes that an increase in the consumption taxation rate would also allow to collect more fiscal resources, and all the more as the preference for private in comparison with public goods consumption is high, whereas on the contrary, a weak consumption taxation rate would imply the risk to have a higher public indebtedness level. Indeed, empirical data show that relying on higher consumption taxes has empirically often been correlated with a better limitation of the weight of the public debt (Estonia or Finland). On the contrary, low consumption taxation rates could be a barrier to the reduction of the public indebtedness level in Greece or in Spain.

Besides, according to our theoretical model, a fiscal policy using capital taxation would have more ambiguous consequences and would be less efficient. First, a higher capital taxation rate would be less efficient than an increase in other taxation rates, in order to increase the fiscal base and to reduce the debt to GDP ratio in a country member of a monetary union. It would be particularly inefficient if the capital share in the production function is weak. Besides, in a framework of tax competition, if the capital taxation rate is then higher than the average capital taxation rate in the rest of the monetary union, tax evasion towards foreign countries could deteriorate this fiscal base, and increase the public indebtedness level. For example, empirical data show that in the case of France, the excessive capital taxation rate in comparison with the rest of the Euro Area could have contributed to the growth of the public debt level.

So, empirical data show an ambiguous trend between the historical evolution of the implicit capital taxation rates and of the public debt levels in the member countries of the Euro Area. However, if we consider the relative situations of these member countries for a specific date, it appears that only the less indebted countries can afford to have low capital taxation rates. The most indebted countries must maintain non negligible capital taxation rates in order to get enough fiscal resources to finance both their public expenditure and the reimbursement of their high public debt. Nevertheless, a policy of high capital taxation rates is not an efficient way to collect fiscal resources and to decrease the public debt level. Highly indebted countries do not seem to succeed to solve with the help of high capital taxation rates their fiscal difficulties and their problems of excessive public indebtedness (France). Indeed, as mentioned by our theoretical model, a policy of high capital taxation rates is weakly efficient, in order to collect fiscal resources, particularly in a framework of tax competition.

Our theoretical model gives interesting results on the links between various taxation rates and public debt levels in the member countries of a monetary union, which are globally in conformity with empirical observations. However, this model is very simplified. Therefore, we could usefully extend the current research, in particular by allowing the possibility of time variations in taxation rates. We could also consider that labor supply is not fixed, but can vary according to the real wage or to the preferences between labor and leisure of the economic agents. Finally, we could also distinguish between various public expenditure, which can be more (public infrastructure: transportation, telecommunications, education) or less

(redistributive expenditure, culture…) productive. These paths remain open for future researches.

## Appendix A: Main components of global demand

Using the equality between the demand and supply of capital ($K_{,i}^{s} = K_{,i}^{d}$), and using equations (3), (10), (16) and (17), we obtain the following private consumption level:

$$C_{i,T} = \frac{[(1-t_i^l)(1-\nu)\rho + (1-t_i^k)\nu(1+\rho) - \nu\delta(1-t_i^k)(2-t_i^k)]}{\nu(1-t_i^k)(1+t_i^c)} K_{ii,T} + \frac{(1+\rho-2\delta+\delta t_j^k)(1-t_j^k)}{(1+t_i^c)(1-t_i^k)} K_{ij,T} + \frac{(1-t_i^l)(1-\nu)\rho}{\nu(1-t_i^k)(1+t_i^c)} K_{ji,T} - \frac{1}{(1+t_i^c)} E_T(K_{ii,T+1}) - \frac{(1-t_j^k)}{(1+t_i^c)(1-t_i^k)} E_T(K_{ij,T+1}) - \frac{\rho}{(1+t_i^c)(1-t_i^k)R_T} B_{i,T} + \frac{\rho(1+R_{T-1})}{(1+t_i^c)(1-t_i^k)R_T} B_{i,T-1} \quad (A1)$$

Equations (16), (17), (29) and (A1) imply:

$$G_{i,T} = \frac{[(t_i^c+t_i^l)\rho + t_i^c(1-t_i^k)\nu + (t_i^k-t_i^l)\nu\rho - \nu\delta(1-t_i^k)(2t_i^c+t_i^k)]}{\nu(1-t_i^k)(1+t_i^c)} K_{ii,T} + \frac{[\nu\rho t_i^k(1+t_i^c) - \nu\delta t_i^k(1+t_i^c)(1-t_i^k) + (t_i^c+t_i^l)(1-\nu)\rho]}{\nu(1-t_i^k)(1+t_i^c)} K_{ji,T} + \frac{t_i^c(1+\rho-2\delta+\delta t_j^k)(1-t_j^k)}{(1+t_i^c)(1-t_i^k)} K_{ij,T} - \frac{t_i^c}{(1+t_i^c)} E_T(K_{ii,T+1}) - \frac{t_i^c(1-t_j^k)}{(1+t_i^c)(1-t_i^k)} E_T(K_{ij,T+1}) + \frac{\rho}{(1+t_i^c)(1-t_i^k)R_T} B_{i,T} - \frac{\rho(1+R_{T-1})}{(1+t_i^c)(1-t_i^k)R_T} B_{i,T-1} \quad (A2)$$

Equations (12) and (18) imply the following production level:

$$Y_{i,T} = \frac{\rho}{\nu(1-t_i^k)}(K_{ii,T} + K_{ji,T}) \qquad (A3)$$

So, equations (10), (36), (A1), (A2) and (A3) imply:

$$(X_{i,T} - M_{i,T}) = Y_{i,T} - (C_{i,T} + G_{i,T} + INV_{ii,T} + INV_{ji,T}) = \delta(K_{ii,T} + K_{ji,T}) + \frac{(1-t_j^k)}{(1-t_i^k)}[E_T(K_{ij,T+1}) - (1-2\delta+\rho+\delta t_j^k)K_{ij,T}] - [E_T(K_{ji,T+1}) - (1-2\delta+\rho+\delta t_i^k)K_{ji,T}] \qquad (A4)$$

Furthermore, according to equation (A4), $(X_{i,T} - M_{i,T}) = -(X_{j,T} - M_{j,T})$ implies:

$$[E_T(K_{ij,T+1}) - (1-2\delta+\rho+\delta t_j^k)K_{ij,T}] = -\frac{\delta(1-t_i^k)}{(t_i^k-t_j^k)}(K_{ii,T} + K_{ji,T} + K_{jj,T} + K_{ij,T}) + \frac{(1-t_i^k)}{(1-t_j^k)}[E_T(K_{ji,T+1}) - (1-2\delta+\rho+\delta t_i^k)K_{ji,T}] \qquad (A5)$$

Therefore, by combining equations (A4) and (A5), we obtain:

$$(X_{i,T} - M_{i,T}) = \frac{\delta(1-t_i^k)}{(t_j^k-t_i^k)}(K_{ii,T} + K_{ji,T}) + \frac{\delta(1-t_j^k)}{(t_j^k-t_i^k)}(K_{jj,T} + K_{ij,T}) \qquad (A6)$$

Besides, equations (10), (32), (A1), (A2), (A3) and (A4) imply the following long term values and relative shares of the various components of global demand in GDP:

$$\frac{C_i}{Y_i}=\frac{(1-t_i^l)(1-\nu)}{(1+t_i^c)}+\frac{\nu(1-t_i^k)(\rho-2\delta+\delta t_i^k)}{(1+t_i^c)\rho}+\frac{\nu[(1-t_j^k)(\rho-2\delta+\delta t_j^k)K_{ij}-(1-t_i^k)(\rho-2\delta+\delta t_i^k)K_{ji}]}{(1+t_i^c)\rho(K_{ii}+K_{ji})} \quad (A7)$$

$$\frac{(X_i-M_i)}{Y_i}=\frac{\nu\delta(1-t_i^k)}{\rho}-\frac{\nu[(1-t_j^k)(\rho-2\delta+\delta t_j^k)K_{ij}-(1-t_i^k)(\rho-2\delta+\delta t_i^k)K_{ji}]}{\rho(K_{ii}+K_{ji})} \quad (A8)$$

$$\frac{INV_{ii}}{Y_i}=\frac{\nu\delta(1-t_i^k)}{\rho}-\frac{\nu\delta(1-t_i^k)}{\rho(K_{ii}+K_{ji})}K_{ji} \qquad \frac{INV_{ji}}{Y_i}=\frac{\nu\delta(1-t_i^k)}{\rho(K_{ii}+K_{ji})}K_{ji} \quad (A9)$$

$$\frac{G_i}{Y_i}=\frac{[\nu\rho(t_i^k-t_i^l)-\nu\delta(2t_i^c+t_i^k)(1-t_i^k)+(t_i^c+t_i^l)\rho]}{(1+t_i^c)\rho}+\frac{\nu t_i^c[(1-t_j^k)(\rho-2\delta+\delta t_j^k)K_{ij}-(1-t_i^k)(\rho-2\delta+\delta t_i^k)K_{ji}]}{(1+t_i^c)\rho(K_{ii}+K_{ji})} \quad (A10)$$

## Appendix B: The optimal public indebtedness level

According to equations (9), (A1) and (A2), the optimal public debt level to maximize the utility function of the representative consumer verifies ($\alpha_c G_{i,t}=\alpha_g C_{i,t}$), and thus:

$$-\frac{[(\alpha_c+\alpha_g)\rho(t_i^l-\nu t_i^l+\nu t_i^k)+(\alpha_c t_i^c-\alpha_g)(\rho+\nu-\nu t_i^k)]}{\nu(1-t_i^k)(1+t_i^c)}K_{ii,T}+\frac{\delta[2(\alpha_c t_i^c-\alpha_g)+(\alpha_c+\alpha_g)t_i^k]}{(1+t_i^c)}K_{ii,T}-\frac{(\alpha_c t_i^c-\alpha_g)(1+\rho-2\delta+\delta t_j^k)(1-t_j^k)}{(1+t_i^c)(1-t_i^k)}K_{ij,T}+\frac{(\alpha_c+\alpha_g)(1-t_i^l)(1-\nu)\rho}{\nu(1-t_i^k)(1+t_i^c)}K_{ji,T}-\alpha_c\frac{[(1-\nu)\rho+\nu\rho t_i^k-\nu\delta t_i^k(1-t_i^k)]}{\nu(1-t_i^k)}K_{ji,T}+\frac{(\alpha_c t_i^c-\alpha_g)(1-t_j^k)}{(1+t_i^c)(1-t_i^k)}E_T(K_{ij,T+1})+\frac{(\alpha_c t_i^c-\alpha_g)}{(1+t_i^c)}E_T(K_{ii,T+1})-\frac{\rho(\alpha_c+\alpha_g)}{(1+t_i^c)(1-t_i^k)R_T}B_{i,T}+\frac{\rho(\alpha_c+\alpha_g)(1+R_{T-1})}{(1+t_i^c)(1-t_i^k)R_T}B_{i,T-1}=0 \quad (B1)$$

So, according to equations (17), (A3) and (B1), the optimal nominal public debt level in the country (i) in period (T) in proportion of GDP is as follows:

$$\left(\frac{B_{i,T}}{P_{i,T}Y_{i,T}}\right)=\frac{(1+R_{T-1})(K_{ii,T-1}+K_{ji,T-1})R_{T-1}}{(K_{ii,T}+K_{ji,T})R_T}\left(\frac{B_{i,T-1}}{P_{i,t-1}Y_{i,T-1}}\right)-\frac{\alpha_c(1+t_i^c)(\rho-\rho\nu-\nu\delta t_i^k+\nu\delta t_i^{k2}+\nu\rho t_i^k)}{\rho(\alpha_c+\alpha_g)}+(1-t_i^l)(1-\nu)-\frac{\nu(\alpha_g-\alpha_c t_i^c)(1-t_i^k)}{\rho(\alpha_c+\alpha_g)(K_{ii,T}+K_{ji,T})}[E_T(K_{ii,T+1})-(1+\rho-2\delta+\delta t_i^k)K_{ii,T}]-\frac{\nu(\alpha_g-\alpha_c t_i^c)(1-t_j^k)}{\rho(\alpha_c+\alpha_g)(K_{ii,T}+K_{ji,T})}[E_T(K_{ij,T+1})-(1+\rho-2\delta+\delta t_j^k)K_{ij,T}] \quad (B2)$$

Therefore, we have the following derivatives of this optimal nominal debt to GDP ratio according to the various parameters of our model:

$$\frac{\partial\left(\frac{B_{i,T}}{P_{i,T}Y_{i,T}}\right)}{\partial\left(\frac{K_{ih,T}}{K_{.i,T}}\right)} = -\frac{\nu\left(\alpha_c t_i^c - \alpha_g\right)\left(1-t_h^k\right)\left(\rho - 2\delta + \delta t_h^k\right)}{\rho\left(\alpha_c + \alpha_g\right)} \quad (B3)$$

$$\frac{\partial\left(\frac{B_{i,T}}{P_{i,T}Y_{i,T}}\right)}{\partial\left[\frac{E_T\left(K_{ih,T+1}\right) - K_{ih,T}}{K_{.i,T}}\right]} = \frac{\nu\left(\alpha_c t_i^c - \alpha_g\right)\left(1-t_h^k\right)}{\rho\left(\alpha_c + \alpha_g\right)} \qquad h = i \text{ or } j \qquad (B4)$$

$$\begin{aligned}\frac{\partial\left(\frac{B_{i,T}}{P_{i,T}Y_{i,T}}\right)}{\partial\rho} &= \frac{\nu\delta\left(1-t_i^k\right)\left[\alpha_g\left(2-t_i^k\right) - \alpha_c\left(2t_i^c + t_i^k\right)\right]}{\rho^2\left(\alpha_c + \alpha_g\right)} \\ &- \frac{\nu\left(\alpha_g - \alpha_c t_i^c\right)\left(1-t_i^k\right)}{\rho^2\left(\alpha_c + \alpha_g\right)\left(K_{ii,T} + K_{ji,T}\right)}\left[\delta\left(2-t_i^k\right)K_{ji,T} - E_T\left(K_{ii,T+1}\right) + K_{ii,T}\right] \\ &+ \frac{\nu\left(\alpha_g - \alpha_c t_i^c\right)\left(1-t_j^k\right)}{\rho^2\left(\alpha_c + \alpha_g\right)\left(K_{ii,T} + K_{ji,T}\right)}\left[\delta\left(2-t_j^k\right)K_{ij,T} + E_T\left(K_{ij,T+1}\right) - K_{ij,T}\right] \qquad (B5)\end{aligned}$$

$$\begin{aligned}\frac{\partial\left(\frac{B_{i,T}}{P_{i,T}Y_{i,T}}\right)}{\partial\nu} &= \frac{\left[\left(2t_i^c + t_i^k\right)\delta\alpha_c\left(1-t_i^k\right) - \left(2-t_i^k\right)\delta\alpha_g\left(1-t_i^k\right) + \rho\left(t_i^l - t_i^k\right)\left(\alpha_c + \alpha_g\right)\right]}{\rho\left(\alpha_c + \alpha_g\right)} \\ &- \frac{\left(\alpha_g - \alpha_c t_i^c\right)\left(1-t_i^k\right)}{\rho\left(\alpha_c + \alpha_g\right)\left(K_{ii,T} + K_{ji,T}\right)}\left[\left(\rho - 2\delta + \delta t_i^k\right)K_{ji,T} + E_T\left(K_{ii,T+1}\right) - K_{ii,T}\right] \\ &+ \frac{\left(\alpha_g - \alpha_c t_i^c\right)\left(1-t_j^k\right)}{\rho\left(\alpha_c + \alpha_g\right)\left(K_{ii,T} + K_{ji,T}\right)}\left[\left(\rho - 2\delta + \delta t_j^k\right)K_{ij,T} - E_T\left(K_{ij,T+1}\right) + K_{ij,T}\right] \qquad (B6)\end{aligned}$$

$$\begin{aligned}\frac{\partial\left(\frac{B_{i,T}}{P_{i,T}Y_{i,T}}\right)}{\partial\delta} &= \frac{\nu\left(1-t_i^k\right)\left[\alpha_c\left(t_i^k + 2\delta t_i^c\right) + \alpha_c t_i^k t_i^c\left(1-\delta\right) - \alpha_g\delta\left(2-t_i^k\right)\right]}{\rho\left(\alpha_c + \alpha_g\right)} \\ &+ \frac{\nu\left(\alpha_g - \alpha_c t_i^c\right)\delta}{\rho\left(\alpha_c + \alpha_g\right)\left(K_{ii,T} + K_{ji,T}\right)}\left[\left(1-t_i^k\right)\left(2-t_i^k\right)K_{ji,T} - \left(1-t_j^k\right)\left(2-t_j^k\right)K_{ij,T}\right] \quad (B7)\end{aligned}$$

This value is mostly positive with a plausible calibration of our parameters, as the preference for private consumption ($\alpha_c$) is sufficiently high in comparison with the preference for public consumption, and as the differential between foreign investments realized by both countries and the second term of the expression can be quite negligible in comparison with investment in the national country.

$$\begin{aligned}\frac{\partial\left(\frac{B_{i,T}}{P_{i,T}Y_{i,T}}\right)}{\partial\left(\frac{\alpha_g}{\alpha_c}\right)} &= \frac{\left(1+t_i^c\right)}{\rho\left(K_{ii,T} + K_{ji,T}\right)}\left(\frac{\alpha_c}{\alpha_c + \alpha_g}\right)^2 \\ &\left[\left(\rho - 2\nu\delta + 2\nu\delta t_i^k\right)\left(K_{ii,T} + K_{ji,T}\right) - \nu\left(1-t_i^k\right)\left(\rho - 2\delta + \delta t_i^k\right)K_{ji,T}\right. \\ &+\nu\left(1-t_j^k\right)\left(\rho - 2\delta + \delta t_j^k\right)K_{ij,T} - \nu\left(1-t_j^k\right)E_T\left(K_{ij,T+1}\right) + \nu\left(1-t_j^k\right)K_{ij,T} \\ &\left.-\nu\left(1-t_i^k\right)E_T\left(K_{ii,T+1}\right) + \nu\left(1-t_i^k\right)K_{ii,T}\right] \qquad (B8)\end{aligned}$$

This expression is mostly positive, if $(K_{ii,T+1} \sim K_{ii,T})$, $(K_{ij,T+1} \sim K_{ij,T})$, $(K_{ij,T} \sim K_{ji,T})$.

$$\frac{\partial\left(\frac{B_{i,T}}{P_{i,T}Y_{i,T}}\right)}{\partial t_i^c} = -\frac{\alpha_c}{\rho(\alpha_c+\alpha_g)(K_{ii,T}+K_{ji,T})}[(\rho-2\nu\delta+2\nu\delta t_i^k)(K_{ii,T}+K_{ji,T}) + \nu(1-t_j^k)(\rho-2\delta+\delta t_j^k)K_{ij,T} - \nu(1-t_i^k)(\rho-2\delta+\delta t_i^k)K_{ji,T} - \nu(1-t_i^k)E_T(K_{ii,T+1}) + \nu(1-t_i^k)K_{ii,T} - \nu(1-t_j^k)E_T(K_{ij,T+1}) + \nu(1-t_j^k)K_{ij,T}] < 0 \qquad (B9)$$

This expression is mostly negative, if $(K_{ii,T+1} \sim K_{ii,T})$, $(K_{ij,T+1} \sim K_{ij,T})$, $(K_{ij,T} \sim K_{ji,T})$.

$$\frac{\partial(\frac{B_{i,T}}{P_{i,T}Y_{i,T}})}{\partial t_i^l} = -(1-\nu) < 0 \qquad (B10)$$

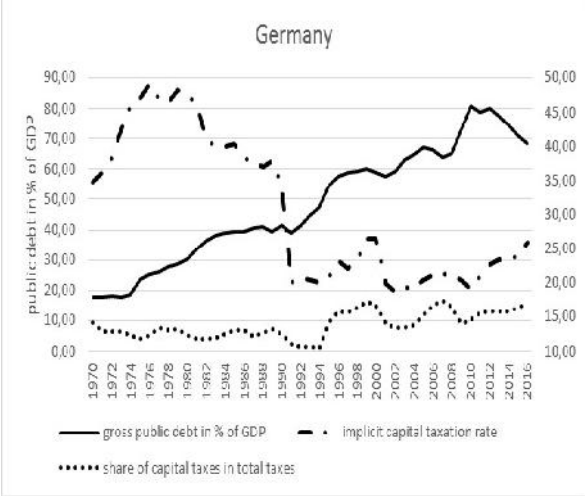
$$\frac{\partial\left(\frac{B_{i,T}}{P_{i,T}Y_{i,T}}\right)}{\partial t_i^k} = -\frac{\nu}{\rho(\alpha_c+\alpha_g)(K_{ii,T}+K_{ji,T})}[\alpha_c(1+t_i^c)(\rho-\delta+2\delta t_i^k)(K_{ii,T}+K_{ji,T}) + (\alpha_g-\alpha_c t_i^c)(\rho-3\delta+2\delta t_j^k)K_{ij,T} + (\alpha_g-\alpha_c t_i^c)(\rho-3\delta+2\delta t_i^k)K_{ii,T} - (\alpha_g-\alpha_c t_i^c)E_T(K_{ii,T+1}) + (\alpha_g-\alpha_c t_i^c)K_{ii,T} - (\alpha_g-\alpha_c t_i^c)E_T(K_{ij,T+1}) + (\alpha_g-\alpha_c t_i^c)K_{ij,T}] \qquad (B11)$$

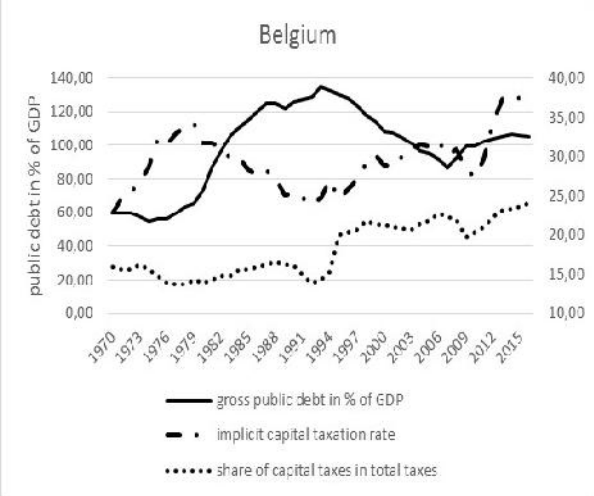
This expression is mostly negative, if $(K_{ii,T+1} \sim K_{ii,T})$, $(K_{ij,T+1} \sim K_{ij,T})$, $(\alpha_g > \alpha_c t_i^c)$.

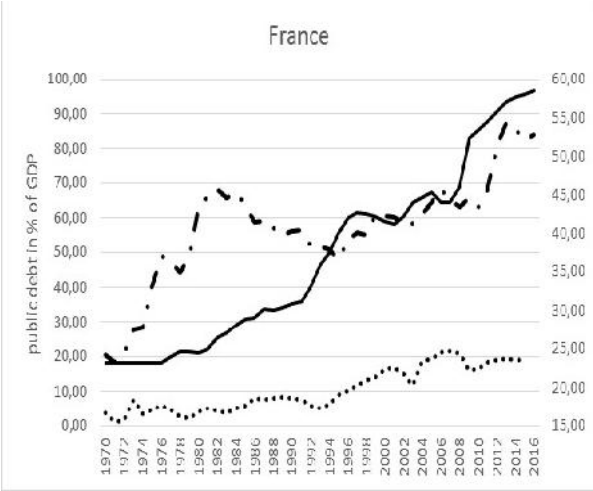
$$\frac{\partial\left(\frac{B_{i,T}}{P_{i,T}Y_{i,T}}\right)}{\partial(t_i^k - t_j^k)} = \frac{\nu(\alpha_g-\alpha_c t_i^c)}{\rho(\alpha_c+\alpha_g)(K_{ii,T}+K_{ji,T})}[(1+\rho-3\delta+2\delta t_j^k)K_{ij,T} - E_T(K_{ij,T+1})] \qquad (B12)$$

## Appendix C: Taxation rates and public debt levels

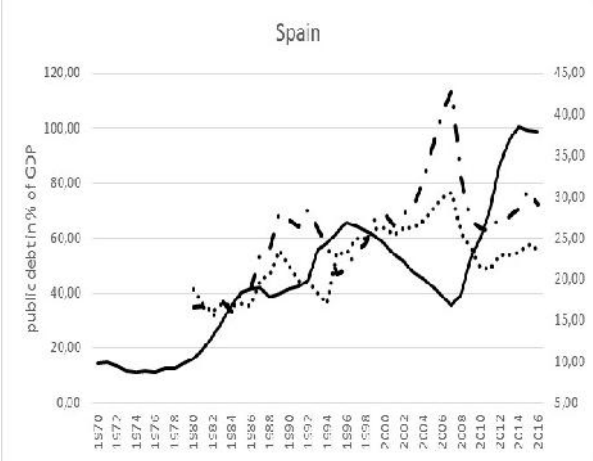
Capital taxation rates and public debt levels

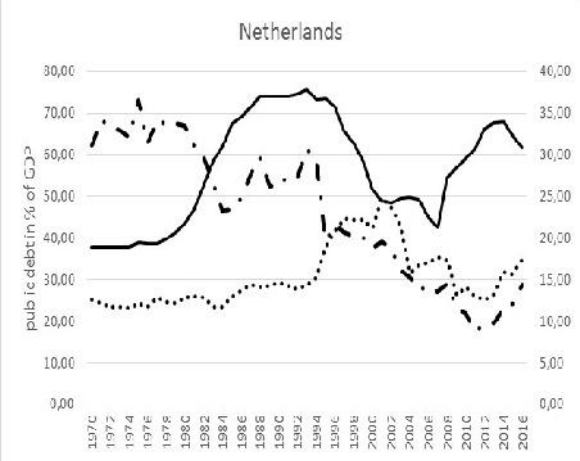


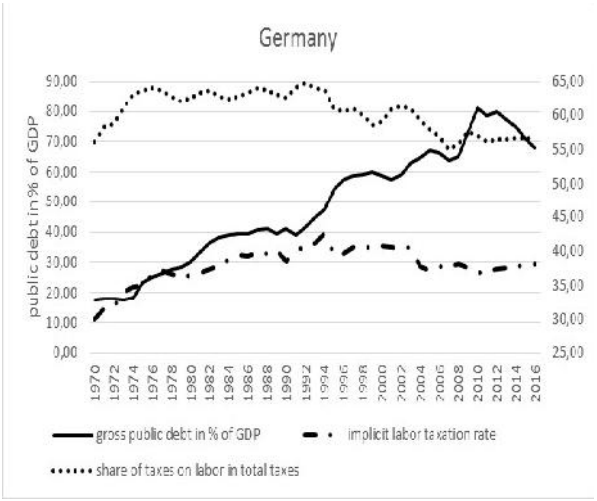



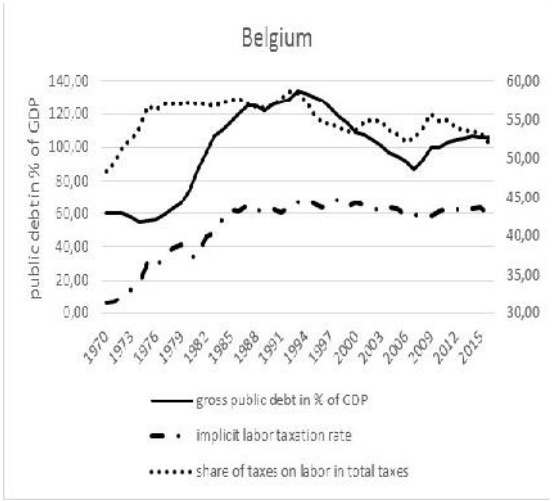


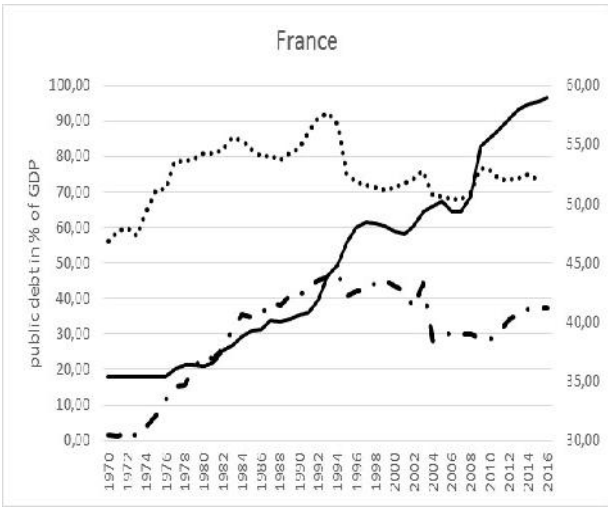


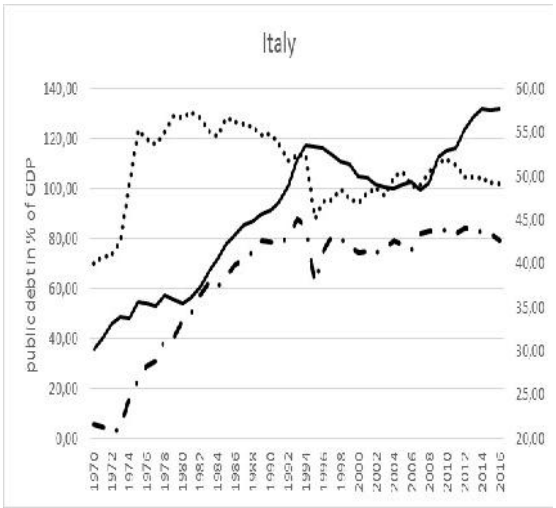



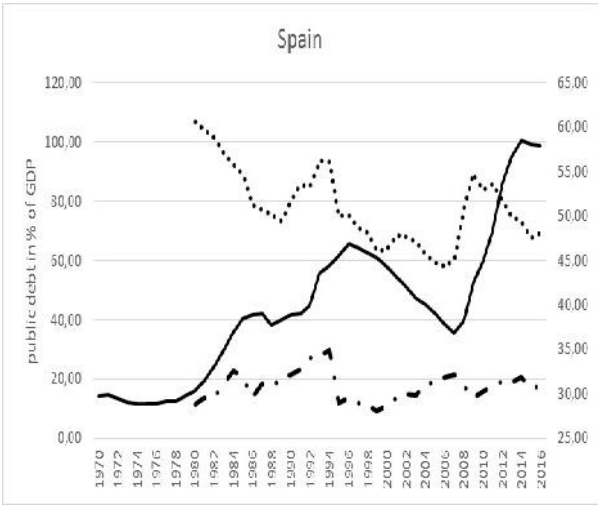

Labor taxation rates and public debt levels

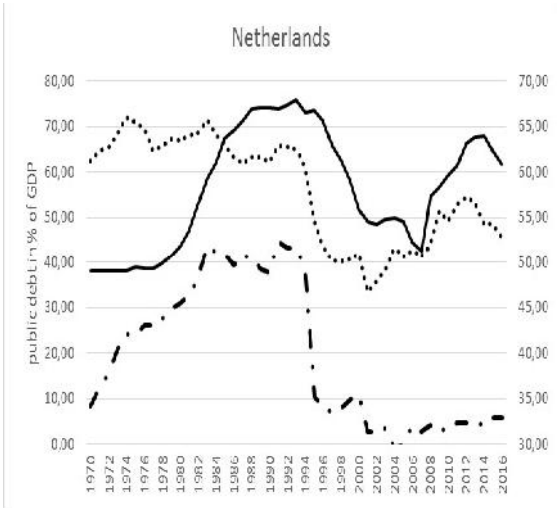


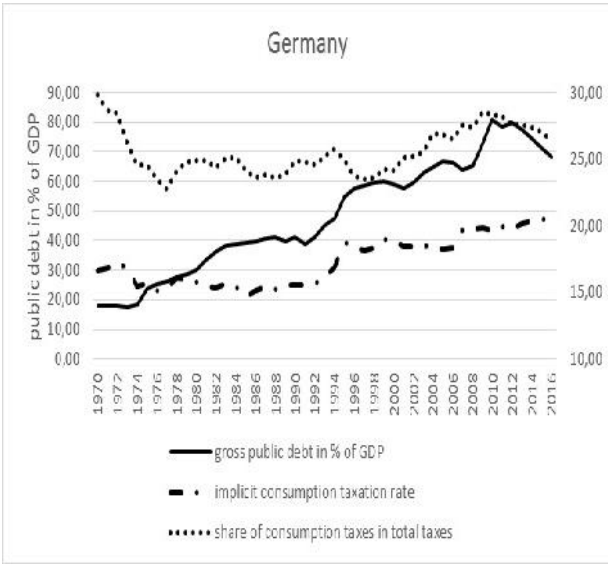



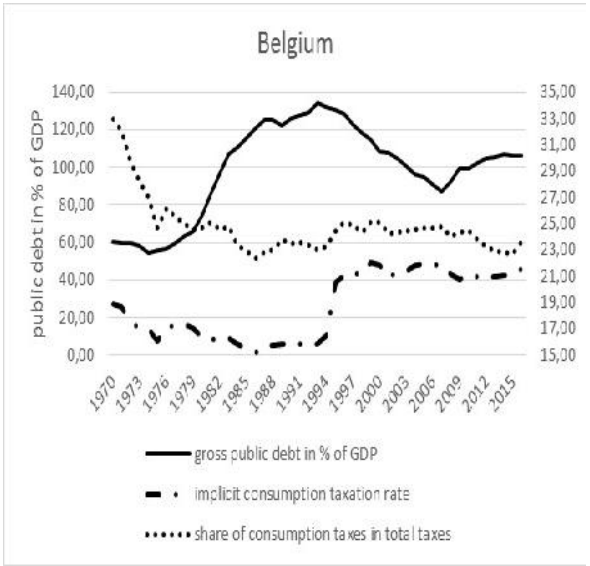



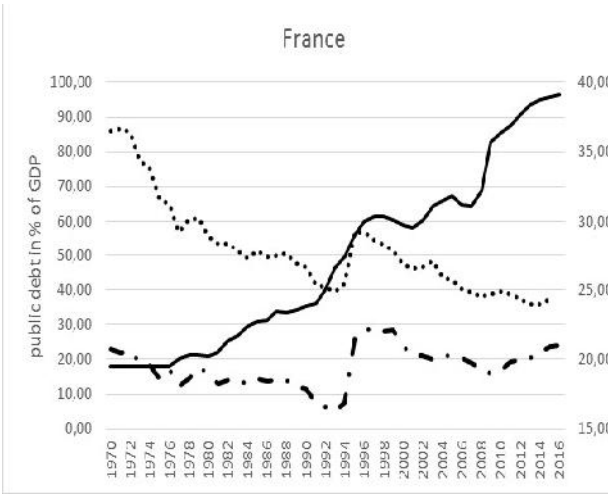



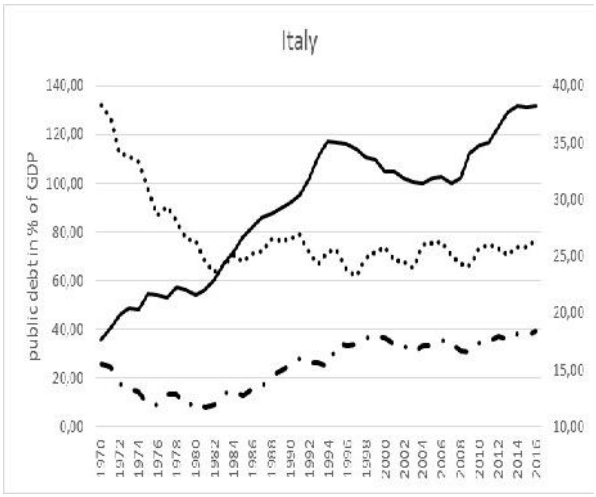



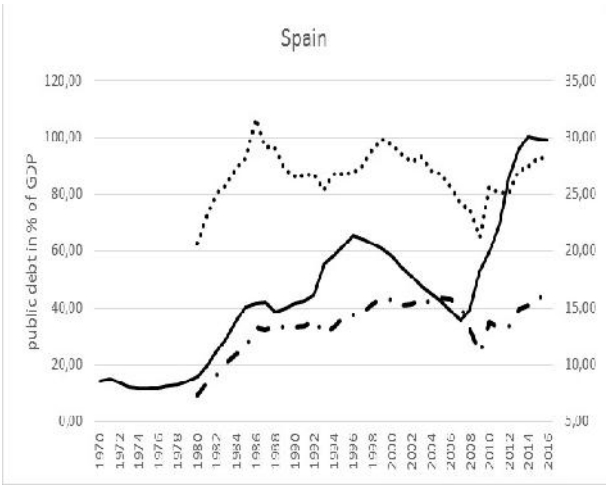

Consumption taxation rates and public debt levels

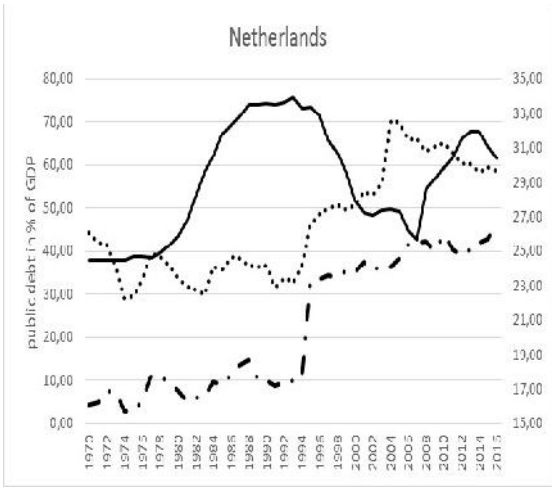



*Source: For taxation rates: European Commission (2000, 2005, 2018), "Taxation trends in the European Union- Data for the EU member States, Iceland and Norway", Eurostat, European Commission.*
*For public debt levels: EUROSTAT.*

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