Labor and profit taxation and the supply of public capital*

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This version: February 2012

Abstract

The paper analyzes the determinants of four fiscal trends, observed in many developed countries over the past 40 years: a decline in the corporate tax rate and public investment offset by an increase in the labour income tax and government consumption. Within a simple neoclassical growth model with a public sector, we illustrate the interdependency between the two government problems of how to spread the tax burden and how to allocate the spending. We identify alternative hypotheses that are consistent with the observed trends, and find that technological changes account for a substantial proportion of the changes in the fiscal instruments. **JEL Classification**: E62; H21; H54.

Keywords: Profit tax; Labor tax, Public Capital.

*We are thankful to Gianluca Benigno, Isabel Correia, Julie Cullen, Nicola Fuchs-Schündeln, Jordi Galì, Roger Gordon, Thomas Laubach, Mark Machina, Albert Marcet, Rachel Ngai, Valerie Ramey, Víctor Ríos-Rull, Loris Rubini, Kevin Sheedy, and to seminar participants at the London School of Economics, Universidad Carlos III Madrid, Goethe University, and the 10th Workshop on Macroeconomic Dynamics (Bologna, 2011) for their valuable comments. Pedro Gomes acknowledges financial support from the Bank of Spain's Programa de Investigación de Excelencia. Contacts: ddebortoli@ucsd.edu, pgomes@eco.uc3m.es

1 Introduction

Over the past four decades most developed countries have experienced similar trends in several government instruments, both on the expenditure and on the taxation side. Compared to the 1960s, many governments are now allocating relatively more resources to government consumption than to public investment and shifted part of the taxation burden from corporate profits to labour income.

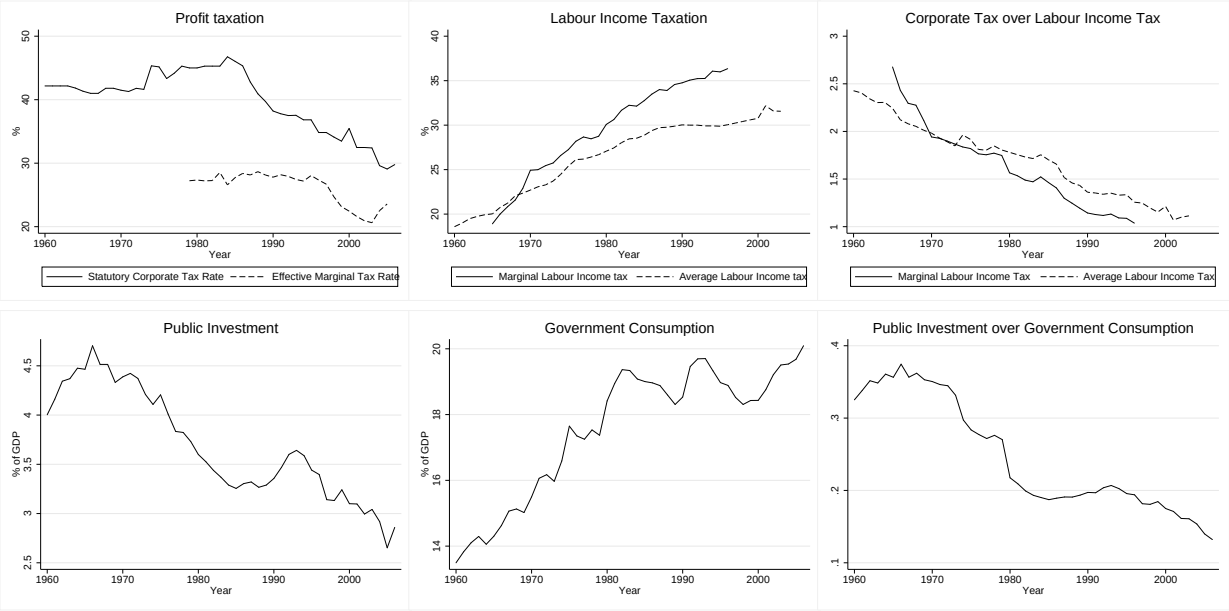
As shown in Figure 1, in the G7 countries government consumption has increased on average from 14 to 20 percent of GDP, while public investment has declined from 4.5 to below 3 percent of GDP. At the same time the statutory corporate tax rate has declined by 15 percentage points, while the marginal labour income tax has increased by 15 percentage points. Most of the OECD countries share at least three of these trends and the decline of the two ratios is generally robust.[1]

There are several possible explanations for these trends. For instance, the decline in the corporate tax rate has been attributed to the higher tax competition [see Devereux, Griffith, and Klemm (2002)]. The increase in government consumption has been related to the increase in openness, either to reduce the risk in international markets [Rodrik (1998)] or because it shifts the burden of taxation abroad giving an incentive for governments to spend [Epifani and Gancia (2009)]. Also, Mehrotra and Välilä (2006) discuss the possible causes for the decline of public investment. Among the most compelling hypotheses is the decreasing need of public infrastructure and the need for fiscal stringency, particularly in Europe. Most of theses studies have analyzed the fiscal trends in isolation. Hence, understanding the reasons behind the co-movements of those trends remains an open question.

This paper proposes a positive analysis which should provide useful insights in explaining these facts. Our theory is based on the idea that there is an intrinsic relationship between the composition of tax revenues and the allocation of public expenditures. We develop this concept within a standard neoclassical growth model with a public sector, where a benevolent government chooses how to allocate the public expenditure between public consumption and investment in productive public capital. Public expenditures are financed by levying taxes on labour income and corporate profits. The concurrence of public capital and profit taxes introduces a link between the choice of how to allocate expenditure and how to finance it.

[1] In a separate online appendix we show the variables disaggregated by country as well as for an average of 20 OECD countries. Most of the countries share the same four trends. The average within country correlation of the ratio of profit taxes over labour income tax, and the ratio of public investment over consumption is around 0.5.

Figure 1: Taxes and allocation of public spending in the G7 countries



Note: The sources for the statutory and effective marginal tax rate are Michigan World tax database and Devereux, Lockwood, and Redoano (2008). The marginal labour income is from Mendoza, Razin, and Tesar (1994). The public investment and the government consumption series are from OECD. The estimates of public capital are from Kamps (2006). Series are an arithmetic mean for: Canada, France, Germany, Italy, Japan, United Kingdom and United States.

Public capital increases the marginal productivity of private factors, partially counteracting the distortions created by the tax system. It also creates economic rents for firms, increasing their profits. The main relationship between the supply of public capital and the composition of taxes is illustrated within a simple model, allowing for an analytical solution.

Through the light of the model, we investigate which factors may account for the observed fiscal trends. We identify two classes of explanations. The first is class is related to "technological changes", making public infrastructures a less important input in the production function. This is a plausible scenario given the change in the economic structure towards a "weightless economy", more centered in services and knowledge-based [see e.g. Quah (1998) or Quah (2001)], or in the presence of investment-specific technological change [see e.g. Greenwood, Hercowitz, and Krusell (1997)], making private capital relatively more productive. As the relative importance of public infrastructure declines, the government reduces public investment and raises government consumption. Additionally, as the firms enjoy fewer rents, the government also reduces the profit tax and compensates it with an increase in the taxation of labour income. The second class of explanations is associated with "fiscal constraints", limiting the choices of one or more fiscal instruments. In our setting, any exogenous constraint in one of instruments affects the optimal choice of the other

three, and can potentially explain the patterns in the data. We find that, for the baseline calibration, an exogenous change in only one instrument cannot explain the four trends. However, arguing that globalization has simultaneously put a downward pressure of profit taxation [Devereux, Griffith, and Klemm (2002)] and increased government consumption [Rodrik (1998) and Epifani and Gancia (2009)], our model would also predict an increase in labour income tax and a decline in public investment. While both explanations can quantitatively account for the change in the ratios of taxes and spending, technological progress can also account for a significant proportion of the changes in all the fiscal instruments. We also explore an alternative hypothesis, based on the increase in preferences for government consumption, but we find it has counterfactual implications for the tax rates and public investment.

From an empirical viewpoint, and as a first attempt to distinguish between these possible explanations, we estimate the determinants of both the tax and spending ratios, for OECD countries between 1965 and 2004. The correlations in the data support the main mechanisms of our model, and suggest that technological changes may have played an important role.

Our work builds on the large fiscal policy literature studying the role of public capital. This includes several works analyzing the effects of different fiscal instruments on economic growth (see e.g. Arrow and Kurz (1970), Barro (1990), Turnovsky (1997, 2000) and Baier and Glomm (2001)), and on business cycle fluctuations (see e.g. Baxter and King (1993) and Lansing (1998)). Our paper aims instead at explaining the behavior of the fiscal instruments themselves, within a model where both taxes and expenditures are determined endogenously.

Many existing studies have analyzed the choice between capital vs labor income taxation. We highlight how that choice may be intrinsically related to the allocation of expenditure across different public goods. In our model, taxing profits constitutes a way to extract the private rents generated by public capital. As a result, corporate taxes are positive also in the long-run – as opposed to the optimality of zero capital taxation in the Judd (1985) and Chamley (1986) framework.[2]

Other authors have explored the relation between profit and capital taxation. Abel (2007) finds that if firms can have immediate expensing, the effective tax rate on capital is always zero, independently of the corporate tax rate. The corporate tax does not, therefore, affect the investment decision of the firms, so the government can raise a substantial amount of

[2]More generally, and as originally shown by Correia (1996) and Jones, Manuelli, and Rossi (1997), when the tax system is incomplete, taxing corporate profits is an indirect way of taxing a factors of production that cannot be taxed directly.

revenue in a non-distortionary way by setting the maximum possible profit tax. Conesa and Dominguez (2006) also distinguish between corporate taxation and dividend taxation in a setting where the firms' rents are generated by the presence of intangible capital. In their setting, corporate tax should be zero in every period. On the other hand, as the government has a non-distortionary dividend tax available, it should set it at the highest possible level, in order to capture the economic rents. In our framework this is not possible because the government has only one instrument available, and the extent to which profit tax is tied to the effective marginal tax rate on capital is exogenous.

The paper continues as follows. In section 2 and 3 we describe the model, illustrate the main intuition within a simple example, and characterize the solution of the optimal policy problem. In section 4 we calibrate the model and analyze the different possible sources of the observed trends in fiscal policy instruments. We conduct an empirical study in section 5 and section 6 concludes the paper.

2 The model

The model is a standard deterministic neoclassical growth model, augmented with productive public capital. The economy is populated by a representative infinitely lived household, with standard preferences given by

$$\sum_{t=0}^{\infty} \beta^t u\left(c_t, g_t, n_t\right), \tag{1}$$

where c_t and n_t denote private consumption and hours worked, respectively. The utility function is also assumed to be separable in all its arguments, and increasing and concave in the amount of public consumption (g_t).[3]

The household rents capital (k_t) and supplies labor to a representative firm, facing distortionary taxes on labor income (τ_t^n) and corporate profits (τ_t^π). Its period-by-period budget constraint is then given by

$$c_t + k_{t+1} = w_t n_t(1-\tau_t^n) + (1+r_t)\,k_t + \Upsilon_t \quad \forall t = 0, 1, 2, ..., \tag{2}$$

where w_t denotes the wage rate, r_t denotes the return on capital net of taxes and depreciation, and Υ_t represents all the lump-sum transfers to the household, in terms of profits or government subsidies.

[3]In previous versions of this paper, we considered a specification where also public capital delivered a utility flow. Since the results are virtually identical, we prefer the current specification that simplifies the exposition of the results.

Output is produced by a representative firm using labor, private and public capital. Following Arrow and Kurz (1970) we consider a constant return to scale production function $y_t = f(k_t, p_t, n_t)$.[4] Taking as given prices $(r_t,\ w_t)$ and policies $(\tau_t^{\pi},\ p_t)$, firms choose the production factors to maximize their after-tax profits, given by

$$(1-\tau_t^{\pi})\left[f(k_t,p_t,n_t) - w_t n_t - \delta^k k_t - \zeta r_t k_t\right] - (1-\zeta) r_t k_t. \tag{3}$$

In writing equation (3) we are assuming that only a proportion $0 \leq \zeta < 1$ of the financial cost of capital can be deduced from the tax base. We motivate this assumption on two grounds. First, the parameter ζ introduces a wedge between the statutory tax and the effective marginal tax rate on capital, a feature consistent with what observed in the data. In the limiting case of $\zeta = 0$, the effective marginal tax rate and the statutory tax rate coincide. Second, the parameter ζ may reflect the firm's financing structure, divided between bonds and equity, which is assumed to be exogenous to our model. Typically, bond interest payments can be deduced from the tax base, while dividends to shareholders cannot.[5] If all the financial costs of capital could be deduced from the tax base (i.e. if $\zeta = 1$), the profit taxation would be non-distortionary, and corporate taxes would always be used to its maximum extent.

In order for the firm's problem to be well-defined, we impose a limit on corporate tax rate $\tau^{\pi} \leq \bar{\tau}^{\pi} < 1$. Otherwise the firm's profits would always be negative, as can be seen in equation (3). Once this limit is imposed, given the positive externality produced by public capital, the firm's profits are strictly positive in equilibrium.

The government provides the public good g_t and the public capital p_t, raising taxes on labor income and corporate profits, subject to the balanced budget condition[6]

$$g_t + p_{t+1} - (1-\delta^p) p_t = \tau_t^n (w_t n_t) + \tau_t^{\pi}\left(y_t - w_t n_t - \delta^k k_t - \zeta r_t k_t\right). \tag{4}$$

[4] A necessary assumption for our considerations is the presence of an equilibrium with positive firm's profits. To preserve positive profits, but departing from the constant returns to scale assumption, one could include an additional factor of production in fixed supply that cannot be taxed (e.g. land or managerial ability), or consider other frictions like monopolistic competitions and limited entry, not explicitly modeled here for simplicity.

[5] This does not seem to be a relevant assumption for our purposes. Although one could argue that this parameter might be endogenous relative to the profit tax, the empirical work of Gordon and Lee (2001) shows that a decline in corporate taxes by ten percentage points (from 46% to 36%) would reduce the fraction of assets financed with debt by only 3.5%.

[6] Since the government can accumulate public capital, the balanced budget condition only limits the possibility of the government to borrow from the private sector. This assumption is made for simplicity and is largely irrelevant for our considerations.

Finally, the aggregate feasibility constraint is given by

$$c_t + g_t + p_{t+1} - (1-\delta^p)p_t + k_{t+1} - (1-\delta^k)k_t = f(k_t, p_t, n_t). \tag{5}$$

We can now define the competitive equilibrium as follows.

Definition 1 *Given an initial stock of private capital (k_0) and public capital (p_0), a competitive equilibrium is a feasible allocation $\{c_t, k_{t+1}, n_t\}_{t=0}^{\infty}$, a policy $\{p_{t+1}, g_t, \tau_t^{\pi}, \tau_t^{n}\}_{t=0}^{\infty}$ and a price system $\{r_t, w_t\}_{t=0}^{\infty}$ such that (i) for given prices, policies and initial capital k_0 the allocation maximizes (1) subject to the sequence of constraints (2) and a no-Ponzi scheme constraint; (ii) In any period t, firms maximize (3), given prices and public capital p_t; (iii) the government satisfies its period by period budget constraint (4).*

It then follows that, in addition to the feasibility constraint (5), the competitive equilibrium is characterized by the following relations:

$$g_t + p_{t+1} - (1-\delta^p)p_t = \tau_t^n (w_t n_t) + \tau_t^{\pi}\left[\frac{1-\zeta}{1-\zeta\tau_t^{\pi}}(f_{k,t} - \delta^k)k_t + f_{p,t}p_t\right]. \tag{6}$$

$$-\frac{u_{n,t}}{u_{c,t}} = f_{n,t}(1-\tau_t^n), \tag{7}$$

$$u_{c,t} = \beta u_{c,t+1}\left[1 + \frac{1-\tau_{t+1}^{\pi}}{1-\zeta\tau_{t+1}^{\pi}}\left(f_{k,t+1} - \delta^k\right)\right], \tag{8}$$

where we used the firm's optimality conditions to substitute for the equilibrium values of w_t and r_t. Moreover, eq. (6) can be obtained from eq. (4), and making use of the homogeneity of degree one of the production function.[7]

Some considerations are in order. First, as indicated by the Euler Equation (8), the ratio $\frac{1-\tau_t^{\pi}}{1-\zeta\tau_t^{\pi}}$ constitutes a wedge between the rate of intertemporal substitution and the marginal returns on capital. That ratio can, therefore, be considered as the effective marginal tax rate on private capital. Second, the government budget constraint (6) indicates that the tax base for corporate taxes is composed by two elements: the returns on private capital $(f_{k,t} - \delta^k)k_t$ and the returns on public capital $(f_{p,t}p_t)$. The presence of the latter term shows why taxing capital income is different than taxing corporate profits. Taxing corporate profits allows the government to appropriate a part of the rents associated with the provision of public capital. This indicates that the supply of public capital and the corporate profit tax rate are two interrelated choices.

[7] As usual, the household's budget constraint is also satisfied, as implied by Walras' Law.

3 The fiscal policy problem

3.1 A simple example with a closed-form solution

Before proceeding to the solution of our complete fiscal policy model, we consider a simple example that illustrates the steady-state relationship between the supply of public capital and the composition of taxes.

In particular, suppose the utility function is given by $u(c,n) = \log(c) - \frac{\phi}{2}\left[\log(n)\right]^2$ (so public consumption has no value), and the production function is $y = k^{\eta}p^{\alpha-\eta}n^{1-\alpha}$, with $\alpha > \eta$. We also assume that both private and public capital fully depreciates each period ($\delta^k = \delta^p = 1$) and we do not allow for any tax deduction for the cost of capital (i.e. $\zeta = 0$) and depreciation. In this economy, the equilibrium conditions evaluated at steady-state, simplify to

$$\hat{c} \equiv c/y = 1 - \hat{p} - \hat{k} \tag{9}$$

$$\hat{k} \equiv k/y = \beta\eta\left(1-\tau^{\pi}\right) \tag{10}$$

$$\hat{c}\phi\log n = (1-\alpha)\left(1-\tau^{n}\right) \tag{11}$$

$$\hat{p} \equiv p/y = \alpha\tau^{\pi} + (1-\alpha)\,\tau^{n}. \tag{12}$$

We can now consider the taxation problem of a government having to supply an exogenous quantity of public capital (as a share of GDP) $0 < \hat{p} < 1$, and where public consumption is normalized to $g = 0$ (without loss of generality). It is convenient to write the problem in terms of a single policy variable $x \equiv \frac{1-\tau^{\pi}}{1-\hat{p}}$. Thus, we can rewrite the welfare relevant variables $[\hat{c}\,(x) = (1-\beta\eta x)\,(1-\hat{p})]$ and $\phi\log n\,(x) = \frac{1-\alpha x}{1-\beta\eta x} < 1$, solely as a function of x, where the inequality follows from the fact that $\alpha > \eta$.[8] We can then obtain the steady-state (indirect) utility function as

$$U\,(x) \equiv \log\hat{c}(x) + \log y(x) - \frac{\phi}{2}\left[\log\left(n\,(x)\right)\right]^2 \tag{13}$$

which is maximized when

$$\frac{\partial\log\hat{c}}{\partial x} + \frac{\partial\log y}{\partial x} = \underbrace{\left[1-\phi\log n\,(x)\right]}_{>0}\frac{\partial\log n\,(x)}{\partial x} < 0, \tag{14}$$

[8] To do so, we have just replaced eq. (10) into eq. (9) and used (12) to substitute for $(1-\tau^{n})$ into eq. (11).

where $\frac{\partial \log \hat{c}}{\partial x} = -\frac{\beta\eta}{1-\beta\eta x} < 0$, $\frac{\partial \log y}{\partial x} = \frac{\eta}{1-\alpha}\frac{1}{x} > 0$, $\frac{\partial \log n}{\partial x} = -\frac{1}{\phi}\frac{\alpha-\beta\eta}{(1-\beta\eta x)^2} < 0$.[9]

This optimality condition provides a useful insight about our taxation problem. Indeed, notice that eq. (14) only depends on x, but not on τ^π and $\hat{p}$ separately. Thus, the optimal value x remains constant, for any quantity of public capital supplied by the government. This argument indicates that treating public capital as exogenous to the taxation problem is irrelevant for the purposes of the current example. The problem could be reversed and, taking profit tax as exogenous, the optimal choice of capital would yield the same x.

The resulting optimal corporate income tax is a linear function, strictly increasing in $\hat{p}$

$$\tau^\pi = 1 - x^*(1-\hat{p}). \tag{15}$$

with x^* denoting the optimal value of x, satisfying condition (14). Equation (15) can alternatively be viewed as a simple fiscal rule, which may or may not come from the government optimizing behavior.

Finally, we can also show that the ratio between the two tax rates τ^π/τ^n is strictly increasing in $\hat{p}$. Indeed, using the government budget constraint (12), that ratio is given by

$$\frac{\tau^\pi}{\tau^n} = \frac{1}{\tau^n}\frac{1-x}{1-\alpha x} + \frac{(1-\alpha)x}{1-\alpha x}. \tag{16}$$

Totally differentiating this expression w.r.t. to $\hat{p}$, and since x does not change with $\hat{p}$, we have

$$\frac{\partial \frac{\tau^\pi}{\tau^n}}{\partial p} = -\left(\frac{1}{\tau^n}\right)^2 \frac{\partial \tau^n}{\partial p}\frac{1-x}{1-\alpha x} > 0 \Leftrightarrow 1 < x < \frac{1}{\alpha}. \tag{17}$$

To verify the latter condition, notice that for the optimality condition (14) to be satisfied, it must be that $x > \beta^{-1}\left[1-(\alpha-\eta)\right]^{-1} > 1$ (otherwise the LHS would be positive, while the RHS is always negative). Also, by combining eqs. (14) and (12), it can be seen that $x < 1/\alpha$ in all the (relevant) equilibria with $\tau^n < 1$.

We have thus illustrated a simple example where a higher supply of public capital leads to a higher corporate tax rate, both in absolute terms and relatively to labor income taxes, and is thus consistent with the (long-run) co-movements observed in the data.

[9] For simplicity, in this example we only considers the policy that maximizes the steady-state utility, and does not necessarily coincides with the steady-state of the dynamic problem, which is instead analyzed in the following section.

3.2 Optimal fiscal policies

We now characterize the solution to the problem of a benevolent (Ramsey) planner, choosing the the best competitive equilibrium implied by the policies $\{p_{t+1}, g_t, \tau_t^n, \tau_t^\pi\}_{t=0}^\infty$. More formally, the planner's problem is to maximize eq. (1), subject to (5)-(6) and $\tau^\pi \leq \bar{\tau}^\pi$, for given initial conditions p_0 and k_0.

To better understand the interactions between the tax rates and the composition of public expenditure, we can look at the first-order optimality condition with respect to the corporate tax rate, given by

$$\mu_{1,t}\left[f_{p,t}p_t + \frac{1-\zeta}{\left(1-\zeta\tau_t^\pi\right)^2}\left(f_{k,t}-\delta^k\right)k_t\right] = \lambda_{t-1}u_{c,t}\left(f_{k,t}-\delta^k\right)\frac{1-\zeta}{\left(1-\zeta\tau_t^\pi\right)^2}, \tag{18}$$

where $\mu_{1,t}$ and λ_{t-1} represent the shadow values of relaxing constraints (6) and (8), respectively.[10] The left-hand side of (18) represents the marginal benefits of increasing profit taxes due to the higher tax revenues. An increase in τ^π increases the revenues from public capital income (first term in the square brackets) and increases the effective marginal tax rate (as given by the ratio $\frac{1-\zeta}{(1-\zeta\tau_t^\pi)^2}$) applied to private capital income (last term in the brackets). An increase in τ^π also generates some welfare costs due to the interest rate distortions, as indicated in the right-hand side of (18). At an optimum, the planner equalizes these marginal costs and benefits. We can rewrite equation (18) as

$$\zeta\tau_t^\pi = 1 - \sqrt{\frac{(f_{k,t}-\delta^k)k_t(\lambda_{t-1}u_{c,t}-\mu_{1,t})(1-\zeta)}{\mu_{1,t}f_{p,t}P_t}}, \tag{19}$$

There are three elements that affect the choice of the tax rate. The first one is the extent to which the profit tax is tied to the effective marginal tax rate. If $\zeta = 1$, the firm can deduce all costs of capital from the tax base, corporate taxation becomes non-distortionary and the optimal tax rate is the upper-bound $\bar{\tau}^\pi$. In that case, the government could retrieve the maximum rents created by public capital. If $\zeta \neq 1$, the tax rate is distortionary and the government chooses it by balancing two opposite effects. On the one hand, the more distortionary the tax rate is, captured by the multiplier of the Euler equation, the lower the tax rate. On the other hand, it is increasing on the size of the rents $f_{p,t}p_t$ and on the shadow value of government revenue $\mu_{1,t}$. From these considerations it follows that the optimal level of corporate taxes is increasing on the amount of public capital supplied.

Also, the composition of public spending depends on the tax rates. This is clear when

[10] For illustrative purposes only, we are assuming that the constraint $\tau^\pi \leq \bar{\tau}^\pi$ is not binding. Notice that the latter constraint will always be binding in $t = 0$ but not in steady-state.

combining the first order conditions of government consumption and public capital, given by

$$\begin{aligned} u_{g,t} &= \beta\mu_{2,t+1}\left[(1-\delta^p)+f_{p,t+1}\right]+ \\ &\quad \beta\mu_{3,t}(1-\tau_t^n)f_{pn,t+1}+\beta\lambda_t u_{c,t+1}\frac{1-\tau_{t+1}^{\pi}}{1-\zeta\tau_{t+1}^{\pi}}f_{pk,t+1}+ \\ &\quad \beta\mu_{1,t+1}\mathcal{R}_{P,t+1}, \end{aligned} \tag{20}$$

where $\mathcal{R}_{P,t+1} \equiv \left[(1-\delta^p)+\tau_{t+1}^{\pi}\left(f_{pp,t+1}p_{t+1}+f_{p,t+1}\right)+\frac{\tau_{t+1}^{\pi}(1-\zeta)}{1-\zeta\tau_{t+1}^{\pi}}k_{t+1}f_{pk,t+1}+\tau_{t+1}^{n}f_{np,t+1}n_{t+1}\right]$ is the derivative of future government revenues with respect to public capital, while $\mu_{2,t}$ and $\mu_{3,t}$ are the shadow values of relaxing constraints (5) and (7), respectively.[11]

When choosing the allocation of spending between public investment and government consumption, the Ramsey planner equates the marginal benefit of the two types of public goods. If the government had lump sum taxes available, the marginal benefit of public investment would be the increase in future aggregate resources (first line). However, the presence of distortionary taxation gives more incentive for the government to invest. First, by increasing the productivity of private factors – and thus wages and the interest rate – it can stimulate employment and savings, counteracting the effects of distortionary taxes (second line). Second, public capital also increases future tax revenues (third line). In other words, public capital raises the marginal productivity of factors and increases the firm's rents that are taxed. Thus, higher tax rates, particularly the corporate tax rate, increase the return to public investment in terms of future tax revenues and raise the incentive for the government to invest instead of consume.

4 Explaining the comovements of fiscal variables

We proceed next to investigate some possible explanations for the co-movements of our fiscal variables. To that end, we calibrate the model to have some steady-state statistics within the range of the G7 countries during the '60s – the beginning of our sample evidence – and then perform several comparative statics exercises. We specify the per-period utility function

$$u\left(c,g,n\right)=\frac{c^{1-\sigma_c}}{1-\sigma_c}+\psi^n\frac{n^{1-\sigma_n}}{1-\sigma_n}+\psi^g\frac{g^{1-\sigma_g}}{1-\sigma_g} \tag{21}$$

[11] The remaining first-order conditions are reported in Appendix A-1.

and a constant elasticity of substitution production function

$$f(k_t, p_t, n_t) = \underbrace{[\theta p_t^{\gamma} + (1-\theta)(Ak_t)^{\gamma}]^{\frac{\alpha}{\gamma}}}_{\equiv \mathcal{K}_t^{\alpha}} n_t^{1-\alpha}. \tag{22}$$

This production function implies a unitary elasticity of substitution between labor and composite capital ($\mathcal{K}_t$).[12] In turn, composite capital is obtained by combining public and private capital through a production function with a constant elasticity of substitution γ, and where the parameter A measures the productivity of private capital.

We set the discount factor $\beta = 0.96$ so that in steady-state the annual real interest rate is 4%. Furthermore, we set the parameters $\sigma_c = 1$, $\sigma_n = 1$ (log - utility in consumption and hours) and $\sigma_g = 0.85$, which is close to the empirical estimates for the U.S. and the OECD countries [see e.g. Amano and Wirjanto (1997) and Nieh and Ho (2006)].The eight remaining parameters ($\psi_n = 2.51$, $\psi_g = 0.39$, $\theta = 0.21$, $\gamma = 0.24$, $\alpha = 0.40$, $\delta_k = 0.11$, $\delta_p = 0.09$ and $\zeta = 0.56$) are calibrated by minimizing the (sum of square) deviations between some basic statistics implied by the model and their counterpart in the data, as summarized in Table 1.

Table 1: Summary statistics: Data vs Model

	G7 countries	**Model**	
	(Average 1960-1970)	Pareto	Ramsey
Output	–	1.10	1
Hours (prop. of available time)	0.23	0.30	0.24
Private Capital (over GDP)	2.20	2.25	2.05
Public Capital (over GDP)	0.50	0.46	0.50
Private Investment (% GDP)	16.8	24.2	22.0
Public Investment (% GDP)	4.40	4.10	4.50
Gov't Consumption (% GDP)	14.6	14.5	14.6
Statutory Corporate Income Tax Rate	41.7	–	42.8
Effective Corporate Income Tax Rate	28.0	–	22.5
Marginal Labor Income Tax Rate	21.5	–	

Note: The statistics for G7 economies refers to the simple average for the sample 1960-1970. The data sources are described in Appendix A-2. Output in the Ramsey solution is normalized to one.

As emphasized above, a crucial aspect of our analysis is the relative importance of public capital in the production function. Our parameters' values imply a relatively low public capital income share of about 6.3%, which lies within the range of available estimates.[13]

[12] As common in the growth literature, our constant returns to scale production function is consistent with a balanced growth path in the presence of Harrod-neutral technological change, and reduces into the familiar Cobb-Douglas specification as $\gamma \to 0$.

[13] For a recent survey of available estimates, together with a meta-analysis, see Bom and Ligthart (2008). Our value is also close to 5% used by Baxter and King (1993).

The above calibration is then used as a benchmark to analyze the long-run effects of exogenous changes in different parameters, and distinguish between alternative explanations for the observed fiscal trends. We first look at the effects of structural changes, represented by exogenous variations in technology or preferences' parameters. We then analyze the effects of imposing exogenous constraints in one or more fiscal instruments, as it may result from tax competition or other political and institutional constraints (not explicitly modeled). In each case, we change the corresponding parameter as to match the average value of a specific fiscal instrument over the last ten years of our sample, and measure the effects on the remaining instruments.

The choice of focusing on long-run effects, as opposed to the entire transition dynamics, is motivated by the following considerations. Within this simple model, all the transition dynamics would share a similar pattern, dominated by the initial jump and subsequent reduction of profit taxation due the re-optimization of the Ramsey plan. Thus, most of the differences between alternative structural changes arise from their long-run effects. Moreover, and even in the absence of structural changes, transition dynamics from low levels of public or private capital are consistent with the observed trends. The convergence to steady-state is indeed characterized by declining investment in public capital, and increasing government consumption.[14] However, the the tax dynamics would be completely driven by the time-inconsistency of the optimal Ramsey plan.[15] Given the positive focus of our analysis, reporting the long-run effects allows us to isolate the effects of alternative, and arguably more plausible, explanations. These considerations notwithstanding, we do take into account transition dynamics in the empirical analysis of section 5.

4.1 Structural changes

One possible explanation for the observed changes in the composition of taxes and expenditures is the reduction of the relative importance of public capital in the production function. This may result from technological change making private capital relatively more productive than public capital. For example, the negative comovement between the price and the quantity of private equipment investment in the US postwar period has been interpreted as evidence of technological change in the production of new equipment, often referred to as "investment-specific technological progress" [see e.g. Greenwood, Hercowitz, and Krusell (1997)].

[14] A more complete description of the transition dynamics is omitted for brevity, but available online in a companion appendix.

[15] See Klein, Krusell, and Ríos-Rull (2008) and Debortoli and Nunes (2010) for the implications of alternative commitment settings in similar dynamic fiscal policy problems.

Within our model, these types of technological changes can be achieved with either a decline in the parameter θ or an increase in the parameter A. We change those parameters to match the observed decline of public investment from about 4.5% to 3.1% of GDP, which requires either an decrease in θ from 0.21 to 0.15, or an increase in A from 1 to 4.[16] In either case, this would imply a relatively small reduction of the public capital income share from 6.3% to around 4.3% of GDP. Results are summarized in the first three columns of Table 2.

As private capital becomes more productive, the government reduces the corporate tax rate to extract a smaller fraction of the rents. For example, as the share of public capital in the production function is zero (i.e. as $A \to \infty$ or $\theta \to 0$), the model is equivalent to the standard model of optimal dynamic taxation. There are no rents in production, so the optimal steady-state profit tax rate is zero. Labor taxes are increased both for a revenue and a substitution effect, and thus the ratio between corporate and labor taxes decreases.

On the expenditure side there is a transfer of resources from public investment to government consumption. This is for two reasons. First, because the return on public capital is lower, and thus public investment is less profitable. Second, because public capital has a less power counteracting the distortions of the tax system, as well as a dimmer impact on the stream of future tax revenues. As a result, the public to private capital ratio decline, as well as the ratio between public investment and government consumption.

Quantitatively, the increase in A can account for close to 50 percent of the decline in corporate tax, 40 percent of the increase in government spending and around 17 percent of the increase in the labour income tax. Lowering θ does have a bigger effect on the corporate tax, explaining 70 percent of the fall, but the effects of the labour tax rate and government consumption, albeit in the right direction are quantitatively very small. The difference is that while an increase in A, implies an increase in overall productivity, a decline in θ is just a shift from public to private capital. This can be seen in the last three rows, showing the implications for non-fiscal variables. Both the change in A and θ have quantitative consistent implications for private investment and capital. However, while changes in θ hardly affect output per capita, the increase in A is associated with a cumulated growth of 220 percent, in line with what observed in the data over a period of 35 years.

An alternative explanation for the rise in government consumption could be the increase in the size of governments, reflecting a higher appetite for public goods of self-interested

[16]The fourfold increase in A is consistent with the evidence in Gordon (1990), Greenwood, Hercowitz, and Krusell (1997), Cummins and Violante (2002) and Fisher (2006), documenting a decline in the relative price of investment by at least a factor of 4 from 1965 to 2004.

Table 2: Explaining the fiscal trends - structural changes

	Baseline	**Tech. change**		**Preferences**	**Data G7 countries**	
		$A = 4$	$\theta = 0.15$	$\psi_g = .477$	1960-1970	1995-2005
Tax rates						
Corporate tax rate (%)	0.43	0.38 (53)	0.37 (70)	0.47 (-49)	0.42	0.33
Labor tax rate (%)	0.23	0.25 (17)	0.23 (2)	0.29 (39)	0.22	0.36
τ^{π}/τ^{n}	1.90	1.51 (38)	1.60 (30)	1.66 (24)	1.94	0.90
Government spending						
Gov't consumption (% of GDP)	0.146	0.162 (37)	0.146 (0)	*	0146	0189
Public investment (% of GDP)	0.045	*	*	0.046 (-7)	0.044	0.031
i^{p}/g	0.31	0.19 (83)	0.21 (68)	0.24 (41)	0.30	0.16
Non-fiscal variables						
GDP per capita	1	2.16 (80)	1.05 (4)	0.97 (-1)	1	2.52
Private capital (% of GDP)	2.05	2.21 (60)	2.22 (63)	2.02 (-14)	2.19	2.47
Private investment (% of GDP)	0.220	0.236 (104)	0.237 (111)	0.216 (-26)	0.168	0.180

Note: In parenthesis is the percentage of the total variation in the data accounted for by the model under the corresponding parameter change. In each row, asterisks denote the instruments targeted when changing the corresponding parameter(s). The statistics for G7 economies refers to the simple average for the sample 1960-1970 and 1995-2005. The data sources are described in Appendix A-2. GDP per capita is normalized to 1 in the initial point.

politicians and/or the underlying society.[17] We use our model to investigate this hypothesis and examine the effects on the remaining instruments. In particular, we increase the value of the utility parameter ϕ_g to match the increase in government consumption from 14.6% to 18.9% of GDP. As reported in fourth column of Table 2, this hypothesis can account for the increase in the labour income tax, but it implies an increase in both the corporate tax rate and public investment, which is inconsistent with the data. As the government needs to increase taxes to finance the higher consumption, it raises the distortions in the economy, thus increasing the incentive for building public capital. This explanation is also inconsistent in its implication for private investment.

4.2 Fiscal constraints

Our model provides a laboratory to investigate the implications of particular exogenous movements in an instrument – say for political or economic conditions – for the allocation of spending and the division of the tax burden. We analyze the effects of constraining each of the four instruments. The results are shown in Table 3.

As the corporate tax rate decreases exogenously, the government tries to get additional revenue by raising the labour income tax. However, as total revenue falls, there is a reduction in all types of expenditures, particularly the government consumption. As government consumption increases exogenously, both taxes go up in order to raise revenue, particularly

[17] In our representative agent model, and given that public expenditure enters separably in the utility function, the parameter ϕ_g may indifferently reflect the preferences of citizens or those of the self-interested politicians.

Table 3: Explaining the fiscal trends - fiscal constrains

	Baseline	**Taxation**		**Spending**		**Combination**	**Data G7 countries**	
		$\tau^{\pi} = 0.33$	$\tau^{n} = 0.36$	$g/y = 18.9\%$	$i^{p}/y = 3.1\%$	g/y and τ^{π}	1960-1970	1995-2005
Tax rates								
Corporate tax rate (%)	0.43	*	0.02 (457)	0.47 (-50)	0.40 (27)	*	0.42	0.33
Labor tax rate (%)	0.23	0.24 (12)	*	0.29 (39)	0.21 (-7)	0.32 (62)	0.22	0.36
τ^{π}/τ^{n}	1.90	1.35 (55)	0.04 (184)	1.66 (24)	1.89 (1)	1.02 (87)	1.94	0.90
Government spending								
Gov't consumption$^{\$}$	0.146	0.143 (-7)	0.170 (55)	*	0.147 (3)	*	0.146	0.189
Public investment$^{\$}$	0.045	0.044 (9)	0.051 (-46)	0.046 (-10)	*	0.044 (8)	0.044	0.031
i^{p}/g	0.31	0.31 (1)	0.30 (4)	0.25 (44)	0.20 (70)	0.23 (53)	0.30	0.16
Non-fiscal variables								
GDP per capita	1	1 (0)	0.96 (-2)	0.97 (-1)	0.97 (-1)	0.97 (-1)	1	2.52
Private capital$^{\$}$	2.05	2.12 (25)	2.24 (70)	2.02 (-14)	2.10 (18)	2.12 (25)	2.19	2.47
Private investment$^{\$}$	0.220	0.227 (44)	0.239 (124)	0.216 (-29)	0.225 (30)	0.227 (43)	0.168	0.180

Note: In parenthesis is the percentage of the total variation in the data accounted for by the model under the corresponding parameter change. In each row, asterisks denote the instruments targeted when changing the corresponding parameter(s). The statistics for G7 economies refers to the simple average for the sample 1960-1970 and 1995-2005. The data sources are described in Appendix A-2. $^{\$}$ in percentage of GDP. GDP per capita is normalized to 1 in the initial point.

the labour income tax. On the other hand, although the government consumption drains so much revenue, there are more incentives for the government to invest because of higher taxes, such that it is optimal to increase public investment.

When one instrument changes for exogenous reasons, there is a revenue and a substitution effect. The substitution effect comes directly from the first-order conditions of the Ramsey problem, altering the ratios of spending and taxes. However, when the government exogenously increases one type of expenditure, it will require higher revenue which will push both tax rates up. Similarly, when it decreases one tax rate, it will generate lower revenue, so it forces both types of spending to go down. In most of the cases considered the revenue effects overcomes the substitution effect. Therefore, although we can explain the comovement between the two ratios with exogenous changes in only one instrument, we do not obtain the appropriate comovement between the four instruments.

The four trends can instead be attributed the combination of a decline in profit tax together with an increase in government consumption, which in turn can be seen as the effects of globalisation. In this respect, Rodrik (1998) and Epifani and Gancia (2009) argue that the increase in the size of government is a consequence of the increase in openness, either because it raised the demand for insurance and public transfers or because trade lowers the domestic cost of taxation. The decline in the corporate tax rate is usually attributed to international tax competition and a higher degree of capital and profit mobility (see Devereux, Lockwood, and Redoano (2008)). In addition to their results, we find that combining the decline in the corporate tax rate and the increase in government consumption could account for 60 percent

of the increase labour income tax, and for only 6 percent of the decline of public investment.

In summary, our analysis suggests that technological changes may have played an important role in generating the four co-movements observed in the data. On the contrary, we found that exogenous changes in preferences or in the supply of public goods are inconsistent with the data, unless one considers a more complex combination of different fiscal constraints. Distinguishing between these alternative hypotheses is of primary importance. As opposed to technological progress or changes in preferences, fiscal constraints, even if they are the optimal response to some exogenous events, are associated with welfare costs. For instance, according to our calibration, limiting both government consumption and corporate taxes would be equivalent to a permanent reduction in consumption of about 6.5 percent (calculated taking into account the transition between steady-states).

4.3 Robustness

We have explored the robustness of our results to alternative calibrations. For instance, Table 4 reports the result under different values of the curvature parameters in the utility function, exogenously fixed in our baseline calibration.[18] First, we have increased the value of σ_n from 1 to 4, in order to have an aggregate Frisch elasticity of labor supply of about 0.77, in line with the recent results of Chetty, Guren, Manoli, and Weber (2011). Second, we have set the parameter $\sigma_g = 1$ so that curvature in public and private consumption are equal. In both cases, the remaining parameters are re-calibrated according to the procedure described in the previous sub-sections.

The main difference with respect to our baseline calibration is that as σ_g increases, technological changes account for a smaller proportion of the change in public consumption (less than 2%). As the supply of g becomes relatively inelastic to changes in other economic conditions, the economy resemble one where public expenditure is fully exogenous. On the contrary, because of the strong interdependence between the supply of public capital and profit taxation, the model accounts for high proportions of the change in the tax and spending ratios.

[18] In separate exercises, we found that behavior of the fiscal instruments is monotone in changes of other preferences and technological parameters, and on fiscal constraints. Thus, our comparative statics exercises are largely insensitive to the particular initial values of those parameters. Specific results are available in a companion online appendix.

Table 4: Explained proportions under alternative calibrations

	Tax rates			Gov't Spending		
	Profit	Labor	Ratio	Consumption	Investment	Ratio
$\sigma_n = 4$						
Higher A	34.1	18.2	27.9	43.8	*	76.4
Lower θ	76.5	1.22	28.8	-0.58	*	54.5
Fiscal Constraints (g and τ^π)	*	50.2	60.0	*	2.95	30.2
$\sigma_g = 1$						
Higher A	65.9	1.19	26.5	1.98	*	53.6
Lower θ	68.8	1.17	27.5	1.93	*	53.5
Fiscal Constraints (g and τ^π)	*	59.3	78.7	*	8.78	37.6

Note: The table reports the proportion (in percent) of the observed change in fiscal instrument accounted for by the model. In each row, asterisks denote the instruments targeted when changing the corresponding parameter(s).

5 Empirical study

5.1 Methodology

The empirical part consist of the estimation of two equations of the composition of spending ($\frac{i^g_{it}}{g_{it}}$) and the tax ratio ($\frac{\tau^\pi_{it}}{\tau^n_{it}}$), for OECD countries. Our objective is not to find unambiguous evidence of causality, but to simply look at correlations that: i) support the mechanisms of the model and ii) find which explanations for the change in tax structure and allocation of spending are more consistent with the data. Therefore, we estimate both equations with panel fixed effects.

Tax structure

We include in the equation of the tax structure two main regressors, reflecting the main endogenous mechanisms of the model. The first one is the ratio of public to private capital $\frac{p_{it}}{k_{it}}$. Given a certain level of total capital, a higher proportion of public capital, means that firms benefit of more economic rents, so the governments have a bigger incentive to tax profits. The second one is the total amount of capital stock in the economy, both public and private: $\frac{k_{it}+p_{it}}{y_{it}}$. We can interpret this variable, as reflecting the dynamic transition to equilibrium.

$$\frac{\tau^\pi_{it}}{\tau^n_{it}} = \alpha_i + \gamma_1 \frac{p_{it}}{k_{it}} + \gamma_2 \frac{k_{it}+p_{it}}{y_{it}} + Exogenous factors_{it} + Controls_{it} \tag{23}$$

We then have a second group of variables, that we use to proxy for exogenous factors that might be responsible for the change in the tax structure. *Services* is the share of value added of the service sector in GDP. We take it as a proxy for structural change to an economy more based in information and communications technology, internet, intellectual assets, financial and consulting services and biotechnology. These industries are, arguably, less dependent on

public capital (corresponding to a decline of the elasticity of output with respect to public capital). They still rely on some government services, such as the legal system or patent protection, which correspond to government consumption but not to public capital. We include the log of *GDP per capita* as a proxy for technological growth, given that we control for the total level of capital in the economy. *Openness* measures the sum of imports and exports as a fraction of GDP, is a proxy for globalization.

We include several types of controls. Some are related to elements of the budget such as the budget deficit and the consumption tax. Others are elements of political nature like the percentage of left wing seats in the parliament and a dummy for election years. The unemployment rate is included to control for the cyclicality of some instruments. We also include a measure of education attainment and the log of population.

Allocation of spending

To understand the behaviour of expenditure side, we run regressions with the ratio of public investment to government consumption as a dependent variable. The model, would predict that the higher level of overall taxation, the more would the government increase investment to counteract the distortions created. Of the overall taxation, the effect should be stronger the higher are profit taxes. We therefore include both τ_{it}^n and $\frac{\tau_{it}^\pi}{\tau_{it}^n}$ in the regressions. To capture transition dynamics, we include both the total level of capital in the economy $\frac{k_{it}+p_{it}}{y_{it}}$ and the ratio of public to private capital $\frac{p_{it}}{k_{it}}$. Additionally, we include the same exogenous factors and controls plus the long-term interest rate.

$$\frac{i_{it}^g}{g_{it}} = \beta_i + \delta_1 \frac{\tau_{it}^\pi}{\tau_{it}^n} + \delta_2 \tau_{it}^n + \delta_3 \frac{k_{it}+p_{it}}{y_{it}} + \delta_4 \frac{p_{it}}{k_{it}} + Exogenous factors_{it} + Controls_{it} \qquad (24)$$

Data

We gather data for 20 OECD countries.[19] For the profit tax, we use the top bracket statutory corporate tax rate from the Michigan World tax database. We use two different series for the labour income taxation. In the baseline estimations we use the measure of marginal labour income tax from Mendoza, Razin, and Tesar (1994). The main drawback of using these data is that it restricts our sample from 1965 to 1996. Therefore, for robustness,

[19]The countries included are Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom and United States.

we use an alternative measure of the average labour income tax from the CEP-OECD Institutions Data Set [Nickell (2006)]. For most countries this variable is available from 1960 to 2004. The estimates of public and private capital are from Kamps (2006). The government consumption, as well as the series of public investment is taken from the *OECD Main Economic Indicators*.

Openness, the share of value added by the service sector over GDP, population and the budget balance are taken from the World Bank World Development Indicators. The GDP per capita is taken from the Penn World Tables. We use two measures of consumption taxes. One is taken from Mendoza, Razin, and Tesar (1994) and the second is taken from the CEP-OECD Institutions Data Set. Unemployment rate and long term interest rate are taken from the *OECD Main Economic Indicators*. Education is the average years of schooling of the population with 15 or above is from the CEP-OECD Institutions Data Set. Finally, the political variables: proportion of left wing vote and the dummy for election years are from the Comparative Parties Data Set.[20]

Before proceeding to the estimation, we checked for multicollinearity by running fixed effects univariate regressions between all the explanatory variables. The R^2 of the regressions between the log of GDP per capita, log of population and the share of services are between 0.57 and 0.66. In between all other variables, the R^2 is below 0.5.

5.2 Results

Table 5 shows the estimations of the determinants of the tax structure (first four columns) and the composition of spending (last four columns). In the columns (1) and (5) we only include the main regressors and a linear time trend. Columns (2) and (6) include the exogenous factors that according to the model might be driving the trends. The remaining columns include the additional controls. In column (4) and (8), the regressions also include country time trends.[21]

Overall, the main correlations suggested by the model are present in the data. First, the tax structure is positively related with the composition of capital. Given a certain amount of total capital stock, a higher proportion of public capital is associated with higher profit tax relative to labour income tax. The variable is significant in all specifications with very high t-statistics. The magnitude of the coefficient of the capital ratio implies that, given

[20]See the Appendix A-2 for a list of the variables, sources and summary statistics.

[21]We also included time dummies instead of country specific time trends, but the results were very similar.

the decline in the sample, this variable is associated with 5 to 15 percent of the overall decline in the tax ratio in the G7 countries. Second, in the estimations of the allocation of spending, both the coefficient of labour income tax and the tax ratio are positive and they are significant in all but one specification.

In the tax equation, the total level of capital in the economy, albeit significant in the first specification, it loses significance when we include the additional controls. We interpret this result as meaning that the transition to steady-state does not affect the tax structure. As it has been pointed out, the theoretical results on the transition dynamics of optimal tax depends on the crucial assumption that the governments can credibly commit to the future path of taxes, which is time inconsistent. The data does not seem to support this mechanism. On the contrary, the transition dynamics seem relevant for the evolution of the spending ratio. The total level of capital is associated with a lower weight of public investment. Furthermore, this effect is much stronger if we start with a lower proportion of public capital relative to private capital, as it was suggested by the model.

Regarding the exogenous factors, a higher share of services, is associated with a lower profit taxation. As the share of services increased in most countries by 10 percentage points, this variable is associated with 15 percent of the decline in the tax ratio in the G7 countries. The coefficient of GDP per capita is not significant in the tax equation when we include further controls. However, it has a very significant negative effect on the ratio of spending. The increase in GDP per capita in OECD countries, is associated with as much as twice the decline of the government investment-consumption ratio. The coefficient of *Services* is also marginally significant with a negative sign for two specifications. All in all, the decline of public investment relative to consumption seems to be mainly driven by technological changes.

Openness, on the other hand, is not correlated with the tax structure. This result is in contrast with several papers that find that openness and tax competition are key determinants of the corporate profit taxes. This discrepancy, might be driven by the fact that our sample does not include the last 15 years, where the tax competition has become more intense. What we can say from our regressions is that, until 1996, openness does not seem to be related with the structure of the tax system. Curiously, *Openness*, is associated with a higher level of public investment rather than a higher level of government consumption. This might suggest that the dimension of international competition until the 90s was actually a phenomenon that forced the governments to increase investment rather than lowering taxes.

Among the remaining variables, only population and political orientation are robustly

Table 5: Determinants of the tax structure and allocation of spending

	Profit-labour tax ratio				Public investment-consumption ratio			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Public-Private	4.144***	3.189***	2.229***	2.170***	-0.519***	-0.898***	-0.869***	-0.884***
capital ratio	(9.01)	(6.61)	(4.25)	(4.03)	(-3.15)	(-5.02)	(-4.74)	(-4.62)
Total capital	0.176***	-0.079	0.075	0.049	-0.243***	-0.301***	-0.348***	-0.329***
	(2.90)	(-1.39)	(1.24)	(0.67)	(-11.96)	(-15.99)	(-15.55)	(-13.01)
Tax ratio					0.054***	0.030	0.045**	0.041**
					(3.53)	(1.47)	(2.32)	(1.98)
Labor tax					0.003*	0.003*	0.005***	0.005***
					(1.89)	(1.86)	(3.24)	(2.96)
Trend	-0.033***	-0.031***	0.011		-0.003***	0.010***	0.011***	
	(-20.21)	(-4.31)	(1.06)		(-3.30)	(3.68)	(3.31)	
Services		-0.011**	-0.022***	-0.021***		0.002	-0.004*	-0.005**
		(-1.96)	(-3.30)	(-2.99)		(1.20)	(-1.79)	(-2.03)
Openness		0.001	-0.001	.0.001		0.001**	-0.000	.0.001
		(0.50)	(-0.69)	(-0.40)		(2.18)	(-0.06)	(1.03)
GDPpc		0.455*	-0.405	-0.469		-0.769***	-0.672***	-0.632***
		(1.90)	(-1.41)	(-1.53)		(-9.45)	(-7.26)	(-6.16)
Pop			-2.875***	-2.900***			-0.096	-0.078
			(-7.86)	(-7.46)			(-0.71)	(-0.53)
Left			0.005***	0.006***			-0.000	-0.000
			(3.60)	(4.02)			(-1.01)	(-0.73)
Election			0.001	-0.002			0.003	0.003
			(0.03)	(-0.13)			(0.64)	(0.46)
Balance			-0.004	-0.001			-0.012***	-0.012***
			(-0.81)	(-0.13)			(-8.03)	(-7.07)
Consumption Tax			0.001	-0.001			0.003	0.003*
			(0.19)	(-0.21)			(1.39)	(1.65)
Unemployment			-0.009	-0.012*			-0.002	-0.000
			(-1.35)	(-1.67)			(-0.73)	(-0.19)
Education			-0.017	-0.013			0.003	0.008
			(-0.71)	(-0.48)			(0.42)	(0.92)
Interest							-0.000	0.002
							(-0.24)	(0.86)
Observations	396	331	312	312	396	331	312	312
Countries	(18)	(18)	(18)	(18)	(18)	(18)	(18)	(18)
Country time trends	No	No	No	Yes	No	No	No	Yes
R^2	0.67	0.70	0.71	0.73	0.53	0.64	0.73	0.74

Note: the sample is from 1965 to 1996. The countries included are Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, New Zealand, Norway, Spain, Sweden, Switzerland, United Kingdom and United States. The regressions are estimated with panel fixed effects. T-statistics reported in brackets. ***,**,* means significance at 1%, 5%, 10%, respectively.

significant across the different specifications. In particular, the larger a country's population, the larger the weight the government puts on labour income taxation, and the more leftist the country is, the higher is capital taxation. Finally, the resulting R^2 is in between 0.53 and 0.74 depending on the specification considered.

5.3 Robustness

We perform some robustness analysis along two dimensions. On the one hand, in order to account for some endogeneity between the regressors, we compute a 3 year averages (average from 2003-2005, 1999-2002 and so forth) of all variables and run the regression with all explanatory variables entering as the lagged 3-year average. On the other hand, we use a measure of average labour income tax for the CEP-OECD Institutions Data Set [Nickell (2006)].[22] This allows us to increase the sample up to 700 observations for 20 countries.

As shown in the Appendix, the results are very similar both in terms of magnitude and significance to the baseline ones. The tax ratio has a high correlation with the public-private capital ratio and the share of services. For the allocation of spending, it is positively associated with the tax ratio, negatively associated with total capital and particularly with GDP per capita. In none of the specifications *Openness* is statistically significant with the expected sign.

6 Conclusion

We argued that considering the joint determination of government expenditures and fiscal revenues may help explaining some basic fiscal trends observed in many countries over the past 40 years. According to our model, both technological change and a particular combination of fiscal constraints are consistent with the evolution of the tax and spending ratios. Importantly, we find that technological changes alone may account for a significant proportion of the changes in the four fiscal instruments. Our empirical analysis, as a first attempt to investigate these relationships, supports the main mechanisms of the model and suggests that technological change may indeed be an important driving force of the co-movements between the profit-labour tax ratio and the government investment-consumption ratio.

In contrast, exogenous increases in the size of governments do not seem consistent with the evolution of the tax rates. However, we cannot exclude the role of more complex political economy factors. In fact, fiscal constraints can have profound impact on public finance beyond their direct effect. For instance, openness and globalization have been indicated in the literature as sources of the increase in government consumption and the decline in

[22]The average labour income tax is the sum of the Employment Tax Rate (employers' social security contributions divided by the sum of total compensation for employees and employers' social security contributions)+Direct Tax Rate (income tax plus employees' social security contributions divided by household current receipts.

corporate taxes. Our analysis shows how those changes may in turn be associated with lower public investment and higher labor income taxes.

One assumption in our paper is that fiscal policies result from optimal decisions. We do not claim that this fully describes the behavior of actual governments. However governments are likely to design fiscal reforms taking into account the composite effects of corporate taxes and subsidies to private firms. Our paper documents the associated positive implications, within an idealized framework. Our insights, we hope, will constitute a useful benchmark for future studies in the fiscal policy and political economy literature.

References

Abel, A. B. (2007): "Optimal Capital Income Taxation," NBER Working Papers 13354, National Bureau of Economic Research, Inc.

Amano, R. A., and T. S. Wirjanto (1997): "Intratemporal substitution and government spending," *Review of Economic and Statistics*, 79(4), 605 – 609.

Arrow, K. J., and M. Kurz (1970): *Public Investment, The Rate of Return and Optimal Fiscal Policy*. The John Hopkins University Press.

Baier, S. L., and G. Glomm (2001): "Long-run growth and welfare effects of public policies with distortionary taxation," *Journal of Economic Dynamics and Control*, 25(12), 2007–2042.

Barro, R. J. (1990): "Government spending in a simple model of endogeneous growth," *Journal of Political Economy*, 98(5), s103–26.

Baxter, M., and R. G. King (1993): "Fiscal Policy in General Equilibrium," *American Economic Review*, 83(3), 315–34.

Bom, P. R. D., and J. Ligthart (2008): ""How Productive is Public Capital? A Meta-Analysis"," Discussion paper, mimeo.

Chamley, C. (1986): "Optimal Taxation of Capital Income in General Equilibrium with Infinite Lives," *Econometrica*, 54(3), 607–22.

Chetty, R., A. Guren, D. Manoli, and A. Weber (2011): "Are Micro and Macro Labor Supply Elasticities Consistent? A Review of Evidence on the Intensive and Extensive Margins," *American Economic Review*, 101(3), 471–75.

Conesa, J. C., and B. Dominguez (2006): "Intangible Investment and Ramsey Capital Taxation," Discussion paper, Univeristat Autonoma de Barcelona.

Correia, I. (1996): "Should capital income be taxed in the steady state?," *The Journal of Public Economics*, 60, 147–151.

Cummins, J. G., and G. L. Violante (2002): "Investment-Specific Technical Change in the United States (1947-2000): Measurement and Macroeconomic Consequences," *Review of Economic Dynamics*, 5, 243–84.

Debortoli, D., and R. Nunes (2010): "Fiscal Policy under Loose Commitment," *Journal of Economic Theory*, 145(3), 1005–1032.

Devereux, M. P., R. Griffith, and A. Klemm (2002): "Corporate income tax reforms and international tax competition," *Economic Policy*, 17(35), 449–495.

Devereux, M. P., B. Lockwood, and M. Redoano (2008): "Do countries compete over corporate tax rates?," *Journal of Public Economics*, 92(5-6), 1210–1235.

Epifani, P., and G. Gancia (2009): "Openness, Government Size and the Terms of Trade," *Review of Economic Studies*, 76(2), 629–668.

Fisher, J. (2006): "The Dyanmic Effects of Neutral and Investment-Specific Technology Shocks," *Journal of Political Economy*, 114(3), 413–451.

Gordon, R. (1990): *The Measurement of Durable Goods Prices*. University of Chicago Press.

Gordon, R. H., and Y. Lee (2001): "Do taxes affect corporate debt policy? Evidence from U.S. corporate tax return data," *Journal of Public Economics*, 82(2), 195–224.

Greenwood, J., Z. Hercowitz, and P. Krusell (1997): "Long-Run Implications of Investment-Specific Technological Change," *American Economic Review*, 87(3), 342–362.

Jones, L. E., R. E. Manuelli, and P. E. Rossi (1997): "On the Optimal Taxation of Capital Income," *Journal of Economic Theory*, 73(1), 93–117.

Judd, K. L. (1985): "Redistributive taxation in a simple perfect foresight model," *Journal of Public Economics*, 28(1), 59–83.

Kamps, C. (2006): "New Estimates of Government Net Capital Stocks for 22 OECD Countries, 1960-2001," *IMF Staff Papers*, 53(1), 6.

Klein, P., P. Krusell, and J.-V. Ríos-Rull (2008): "Time Consistent Public Policy," *Review of Economic Studies*, 75, 789–808.

Lansing, K. J. (1998): "Optimal Fiscal Policy in a Business Cycle Model with Public Capital," *Canadian Journal of Economics*, 31(2), 337–364.

Mehrotra, A., and T. Välilä (2006): "Public Investment in Europe: Evolution and Determinants in Perspective," *Fiscal Studies*, 27(4), 443–471.

Mendoza, E. G., A. Razin, and L. L. Tesar (1994): "Effective tax rates in macroeconomics: Cross-country estimates of tax rates on factor incomes and consumption," *Journal of Monetary Economics*, 34(3), 297–323.

Nickell, W. (2006): "The CEP-OECD Institutions Data Set (1960-2004)," CEP Discussion Papers CEPDP0759, CEP.

Nieh, C.-C., and T. Ho (2006): "Does the expansionary government spending crowd out the private consumption? Cointegration analysis in panel data.," *The Quarterly Review of Economics and Finance*, 46, 133–148.

Quah, D. (1998): "A weightless economy," *The UNESCO Courier*.

Quah, D. (2001): "The Weightless Economy in Economic Development," in *Information Technology, Productivity and Economic Growth: International Evidence*, ed. by M. Pohjola. Oxford University Press.

Rodrik, D. (1998): "Why Do More Open Economies Have Bigger Governments?," *Journal of Political Economy*, 106(5), 997–1032.

Turnovsky, S. J. (1997): "Fiscal Policy In A Growing Economy With Public Capital," *Macroeconomic Dynamics*, 1(03), 615–639.

——— (2000): "Fiscal policy, elastic labor supply, and endogenous growth," *Journal of Monetary Economics*, 45(1), 185–210.

Appendix

A-1 Main derivations of the model

Households and Firms

The household's and firm's optimality conditions are standard and given by

$$
\begin{aligned}
u_{c,t} &= \beta u_{c,t+1}\left(1+r_{t+1}\right), && \text{(A-1)}\\
-\frac{u_{n,t}}{u_{c,t}} &= w_t(1-\tau_t^n). && \text{(A-2)}\\
r_t &= \frac{(1-\tau_t^\pi)}{(1-\zeta\tau_t^\pi)}\left(f_{k\,t}-\delta^k\right), && \text{(A-3)}\\
(1-\tau_t^\pi)\left(f_{n,t}-w_t\right) &= 0. && \text{(A-4)}
\end{aligned}
$$

Combining these equations and imposing $\tau_t^\pi < 1$, we get eq. (8) and (7) in the main text.

Optimality conditions of the Ramsey problem

Given initial conditions p_0 and k_0, the Ramsey planner maximizes eq. (1), subject to (5)-(8) and the upper-bound on profit taxation $\tau_\pi < 1$. After taking derivative to the corresponding Lagrangean formulation, the resulting optimality conditions are:

$$
\begin{aligned}
\tau_t^\pi: \quad & \mu_{1,t}\left[f_{p,t}p_t+\tfrac{1-\zeta}{(1-\zeta\tau_t^\pi)^2}\left(f_{k,t}-\delta^k\right)k_t\right]-\lambda_{t-1}u_{c,t}\left(f_{k,t}-\delta^k\right)\tfrac{1-\zeta}{(1-\zeta\tau_t^\pi)^2}=0\\
\tau_t^n: \quad & \mu_{1,t}f_{n,t}n_t-\mu_{3,t}f_{n,t}=0\\
c_t: \quad & u_{c,t}-\mu_{2,t}-\mu_{3,t}\tfrac{u_{n,t}u_{cc,t}}{u_{c,t}^2}-\lambda_t u_{cc,t}+\lambda_{t-1}u_{cc,t}\left(1+\tfrac{1-\tau_t^\pi}{1-\zeta\tau_t^\pi}(f_{k,t}-\delta^k)\right)=0\\
g_t: \quad & u_{g,t}-\mu_{2,t}-\mu_{1,t}=0\\
n_t: \quad & u_{n,t}+\mu_{2,t}f_{n,t}+\mu_{1,t}\left[\tau_t^n\left(f_{n,t}+f_{nn,t}n_t\right)+\tau_t^\pi\left(\tfrac{1-\zeta}{1-\zeta\tau_t^\pi}f_{kn,t}k_t+f_{pn,t}p_t\right)\right]+\\
& \mu_{3,t}\left[\tfrac{u_{nn,t}}{u_{c,t}}+f_{nn,t}(1-\tau_t^n)\right]+\lambda_{t-1}u_{c,t}\tfrac{1-\tau_t^\pi}{1-\zeta\tau_t^\pi}f_{kn,t}=0\\
k_{t+1}: \quad & -\mu_{2,t}+\beta\mu_{2,t+1}[(1-\delta^k)+f_{k,t+1}]+\\
& \beta\mu_{2,t+1}\left[\tau_{t+1}^n\left(f_{kn,t+1}n_{t+1}\right)+\tau_{t+1}^\pi\left(\tfrac{1-\zeta}{1-\zeta\tau_{t+1}^\pi}(f_{k,t+1}-\delta^k)+\tfrac{1-\zeta}{1-\zeta\tau_{t+1}^\pi}f_{kk,t+1}k_{t+1}+f_{pk,t+1}p_{t+1}\right)\right]\\
& +\beta\mu_{3,t+1}\left[f_{kn,t+1}(1-\tau_{t+1}^n)\right]+\lambda_t\left[\beta u_{c,t+1}\tfrac{1-\tau_{t+1}^\pi}{1-\zeta\tau_{t+1}^\pi}f_{kk,t+1}\right]=0\\
p_{t+1}: \quad & -\mu_{2,t}+\beta\mu_{2,t+1}[(1-\delta^p)+f_{p,t+1}]-\mu_{1,t}+\\
& \beta\mu_{1,t+1}\left[(1-\delta^p)+\tau_{t+1}^n\left(f_{pn,t+1}n_{t+1}\right)+\tau_{t+1}^\pi\left(\tfrac{1-\zeta}{1-\zeta\tau_{t+1}^\pi}f_{kp,t+1}k_{t+1}+f_{p,t+1}+f_{pp,t+1}p_{t+1}\right)\right]+\\
& +\beta\mu_{3,t+1}\left[f_{pn,t+1}(1-\tau_{t+1}^n)\right]+\lambda_t\left[\beta u_{c,t+1}\tfrac{1-\tau_{t+1}^\pi}{1-\zeta\tau_{t+1}^\pi}f_{kp,t+1}\right]=0
\end{aligned}
$$

where μ_1, μ_3 and λ are the Lagrange multipliers associated with constraints (6) - (8), respectively, and μ_2 is the Lagrange multiplier associated with the feasibility constraint (5).

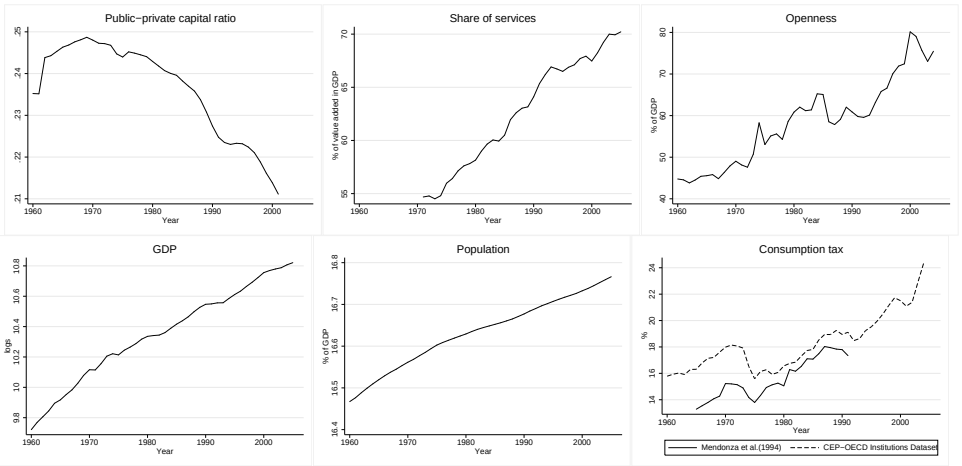
A-2 Data

Table 6: Summary statistics and sources

Variable	Description	Mean	Sd	Min	Max	Source
τ^{π}	Top bracket corporate tax	41.72	8.50	9.8	56	Michigan World Tax Database
τ_1^n	Marginal labour income tax	34.06	9.63	12.40	53.58	Mendonza et al. (1994)
τ_2^n	Average labour income tax	27.32	9.94	5.60	83.50	CEP-OECD Institutions Data Set
$EMTR$	Effective marginal tax rate	28.78	8.80	8.67	47.07	Devereux et al. (2008)
p	Public capital (% GDP)	0.57	0.17	0.27	1.07	Kamps (2006)
k	Private capital (% GDP)	2.54	0.53	1.25	3.81	Kamps (2006)
i^p	Public investment (% GDP)	3.48	1.65	1.49	10.08	Kamps (2006)
g	Gov. consumption (% GDP)	19.57	3.90	7.95	30.13	OECD-MEI
$Services$	Value added of services (% GDP)	61.24	5.29	48.33	72.79	WB -WDI
$GDPpc$	Log of GDP per capita	10.59	1.52	9.15	15.17	Penn World Tables
$Openness$	Openness (% GDP)	53.01	26.42	11.25	145.42	WB - WDI
Pop	Population	16.99	1.28	14.97	19.41	WB -WDI
$Balance$	Budget Balance	-2.10	3.74	-15.71	17.99	WB -WDI
τ_1^c	Consumption tax	15.61	8.13	4.35	40.27	Mendonza et al. (1994)
τ_2^c	Consumption tax	17.79	5.49	2.30	34.30	CEP-OECD Institutions Data Set
$Unemp.$	Unemployment rate	5.46	3.77	.01	20.15	OECD-MEI
$Education$	Average years of schooling	8.24	2.08	1.86	12.05	CEP-OECD Institutions Data Set
$Interest.$	Long term interest rate	8.61	3.85	1.10	31.03	OECD-MEI
$Left$	Left party votes (% total)	36.81	16.55	0	65	Comparative parties dataset
$Election$	Dummy for election year	0.31	0.46	0	1	Comparative parties dataset

Note: MEI-Main Economic Indicators; the comparative party dataset was created by Duane Swank and is available on http://www.mu.edu/polisci/Swank.htm. CEP-OECD Institutions Data Set is available http://cep.lse.ac.uk/_new/publications/abstract.asp?index=2424. The variable education is only available every five years and it is interpolated in between.

Figure A-1: Key explanatory variables (Average for 20 OECD countries)



A-3 Additional estimations

Table 7: Determinants of the profit-labour tax ratio, robustness

	3-year blocks				Average labour income tax			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Public-Private capital	4.122***	3.062***	2.481***	2.462***	4.188***	2.546***	1.549***	1.245**
ratio	(5.55)	(3.82)	(2.94)	(2.89)	(9.48)	(5.72)	(2.88)	(2.38)
Total capital	0.123	-0.126	0.029	-0.049	-0.434***	-0.316***	-0.222***	-0.337***
	(1.28)	(-1.37)	(0.29)	(-0.39)	(-7.86)	(-5.85)	(-3.67)	(-5.45)
Trend	-0.030***	-0.013	0.036**		-0.024***	-0.035***	-0.029***	
	(-10.95)	(1.08)	(2.08)		(-20.99)	(-5.55)	(-3.60)	
Services		-0.022**	-0.041***	-0.039***		0.008*	-0.008*	-0.002
		(-2.28)	(-3.45)	(-3.01)		(1.79)	(-1.68)	(-0.36)
Openness		-0.001	-0.004	-0.007		0.006***	0.007***	0.006***
		(-0.20)	(-1.05)	(-1.42)		(4.06)	(4.59)	(3.26)
GDPpc		-0.023	-1.026**	-1.055**		0.368	0.672**	0.407
		(-0.05)	(-2.11)	(-2.08)		(1.50)	(2.46)	(1.45)
Pop			-2.423***	-2.691***			-1.420***	-2.044***
			(-4.06)	(-4.11)			(-3.36)	(-4.96)
Left			0.006**	0.008***			-0.002	-0.002
			(2.66)	(3.14)			(-1.34)	(-1.30)
Election			0.068	0.025			-0.010	-0.012
			(1.03)	(0.35)			(-0.48)	(-0.60)
Balance			-0.010	-0.005			-0.009*	-0.007
			(-1.23)	(-0.58)			(-1.93)	(-1.49)
Consumption Tax			0.003	-0.004			0.020***	0.026***
			(0.28)	(-0.34)			(4.16)	(5.51)
Unemployment			-0.012	-0.012			-0.004	-0.024***
			(-1.04)	(-0.94)			(-0.65)	(-3.73)
Education			-0.024	-0.030			-0.037	-0.025
			(-0.60)	(-0.69)			(-1.30)	(-0.90)
Observations	119	95	90	90	707	505	495	495
Countries	(18)	(17)	(17)	(17)	(20)	(19)	(19)	(19)
Country time trends	No	No	No	Yes	No	No	No	Yes
R^2	0.72	0.80	0.82	0.84	0.54	0.47	0.54	0.61

Notes: The sample is from 1965 to 2000. The countries included are Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom and United States. The regressions are estimated with panel fixed effects. T-statistics reported in brackets. ***,**,* means significance at 1%, 5%, 10%, respectively.

Table 8: Determinants of the public investment-consumption ratio, robustness

	3-year blocks				Average labour income tax			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Tax ratio	0.085**	0.042	0.098*	0.108*	0.004	0.020*	0.030**	0.044***
	(2.45)	(0.95)	(1.95)	(2.00)	(0.54)	(1.82)	(2.43)	(3.34)
Labor tax	0.005	0.001	0.004	0.003	0.002***	0.002*	0.001	0.002**
	(1.49)	(0.46)	(1.10)	(0.99)	(2.66)	(1.95)	(1.27)	(2.29)
Public-Private capital	-0.949***	-1.253***	-1.047***	-1.063***	0.418***	0.057	-0.041	-0.085
ratio	(-2.88)	(-3.46)	(-2.82)	(-2.77)	(4.07)	(0.48)	(-0.29)	(-0.59)
Total capital	-0.282***	-0.278***	-0.299***	-0.249***	-0.136***	-0.207***	-0.235***	-0.213***
	(-7.90)	(-7.10)	(-7.22)	(-4.93)	(-11.96)	(-15.29)	(-15.55)	(-13.01)
Trend	-0.009*	0.009***	0.013*		0.002	0.000	-0.001	
	(-1.85)	(1.39)	(1.88)		(-1.14)	(0.30)	(-0.71)	
Services		0.003	-0.004	-0.006		0.007***	0.007***	0.006***
		(0.86)	(-0.83)	(-1.13)		(6.84)	(6.16)	(4.40)
Openness		0.002*	0.001	0.003		-0.000	0.000	0.000
		(1.74)	(0.70)	(1.67)		(-0.21)	(0.29)	(0.86)
GDPpc		-0.762***	-0.745***	-0.665***		-0.441***	-0.381***	-0.314***
		(-4.70)	(-3.83)	(-3.16)		(-7.78)	(-5.72)	(-4.35)
Pop			0.038	0.189			0.290***	0.335***
			(0.14)	(0.62)			(2.70)	(2.99)
Left			-0.001	-0.001			0.000	0.001
			(-0.99)	(-1.13)			(1.23)	(1.45)
Election			-0.009	0.006			0.002	0.002
			(-0.34)	(0.20)			(0.36)	(0.37)
Balance			-0.014***	-0.014***			-0.003**	-0.003**
			(-3.98)	(-3.99)			(-2.57)	(-2.08)
Consumption Tax			0.003	0.006			0.001	0.000
			(0.74)	(1.40)			(0.87)	(0.12)
Unemployment			-0.006	-0.004			-0.000	0.001
			(-1.23)	(-0.89)			(-0.15)	(0.77)
Education			0.013	0.023			0.005	0.005
			(0.85)	(1.36)			(0.79)	(0.67)
Interest			-0.002	0.000			-0.001	0.003*
			(-0.72)	(0.12)			(-0.73)	(1.67)
Observations	119	95	90	90	707	505	495	495
Countries	(18)	(17)	(17)	(17)	(20)	(19)	(19)	(19)
Country time trends	No	No	No	Yes	No	No	No	Yes
R^2	0.60	0.67	0.78	0.80	0.52	0.53	0.60	0.62

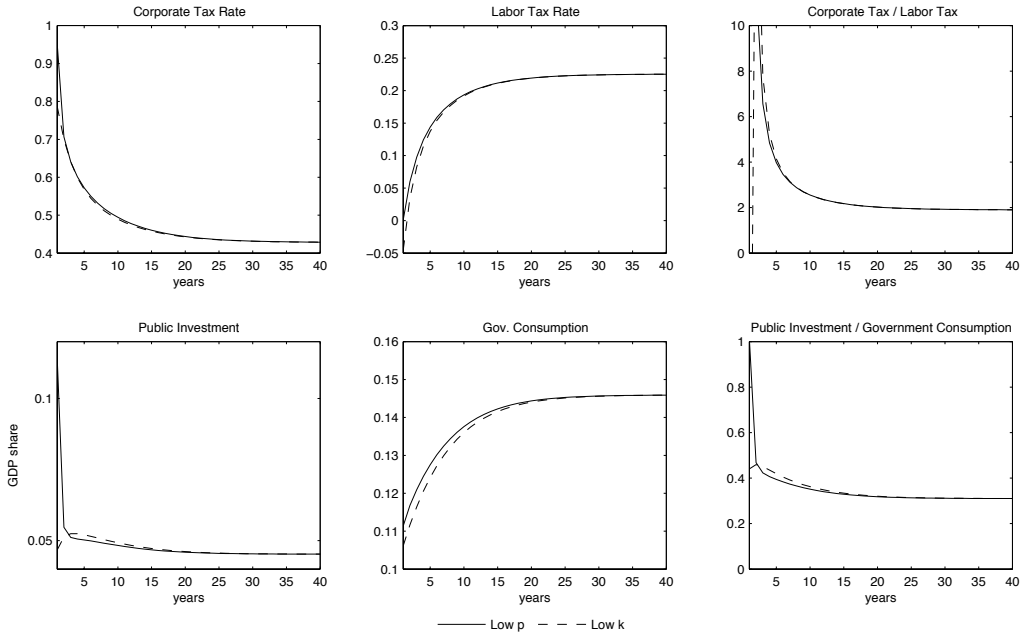
Notes: The sample is from 1965 to 2000. The countries included are Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom and United States. The regressions are estimated with panel fixed effects. T-statistics reported in brackets. ***,**,* means significance at 1%, 5%, 10%, respectively.

Additional material

B.1 Transition to steady state

When examining the transition dynamics of the model, our aim is to understand the role of the accumulation of both private and public capital along the path to steady-state.[23] We then consider two starting points: one with low public capital, where public and private capital are 60 and 20 percent below steady state, and one with low private capital with the inverse proportions. The results are shown in Figure B.1.1.

Figure B.1.1: Dynamic transition to steady state



Note: The figure plots the transition dynamics from low initial levels of public capital (solid line) and low levels of private capital (dash line).

When we start with a lower public capital stock, as the government re-optimizes and the previous plan is made obsolete, it sets the profit tax at the maximum possible. The corporate tax stays at the maximum value for several periods and the labour income goes to very low levels. Together with the reduction of government consumption, it allows for a rapid accumulation of public capital. Along the transition path that takes roughly 20 years, public investment goes down, government consumption increases, corporate tax decreases and labour income tax goes up.

[23] Additional transition dynamics between different steady-states are omitted for brevity and available from the authors upon request.

When starting from a low private capital, the decline of labour income tax is so strong that it turns into a subsidy. Also, the corporate tax rate is not set at the maximum. This is achieved with a sharp reduction of public consumption and a disaccumulation of public capital. In our model, the only savings instrument the government has is public capital. If the level of public capital, relative to private capital, is already high enough the government wants to disinvest and therefore it does not want to set the proft tax to its maximum.

B.2 Changes in parameters

Figure B.2.2: Effects of technological progress

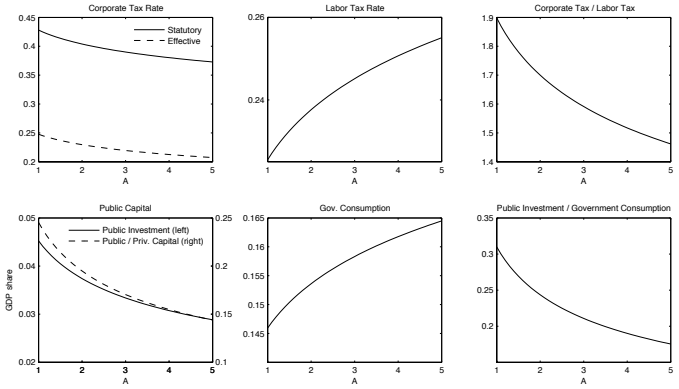


Figure B.2.3: Effects of changes in θ

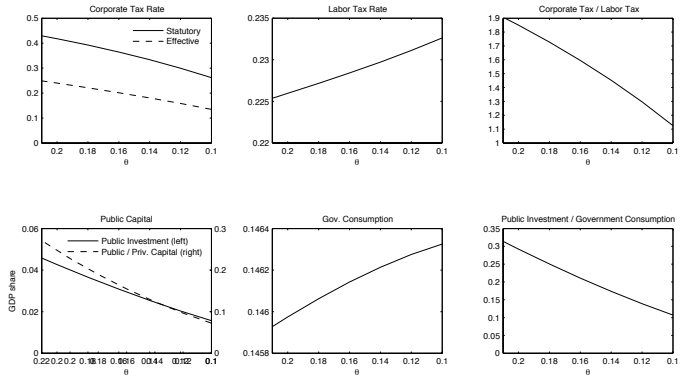
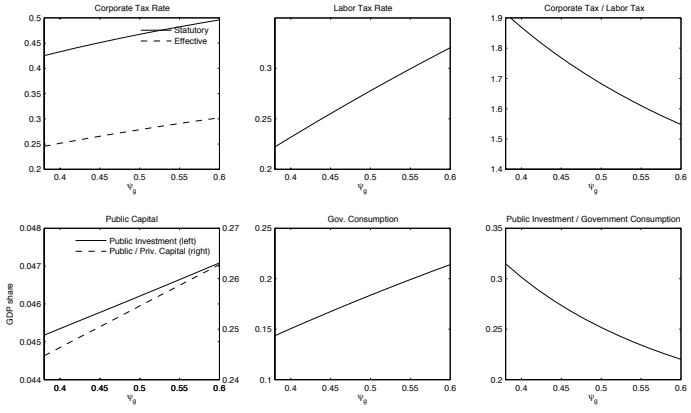


Figure B.2.4: Effects of changes in preferences for government consumption



B.2.1 Exogenous changes in instruments

Figure B.2.5: Steady-state effects of exogenous changes in profit tax

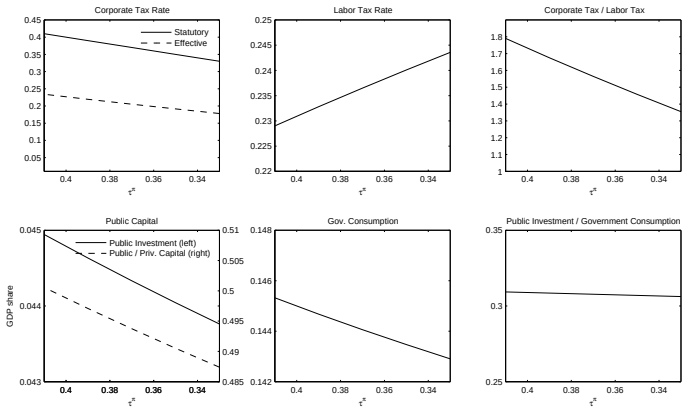


Figure B.2.6: Steady-state effects of exogenous changes in labor tax

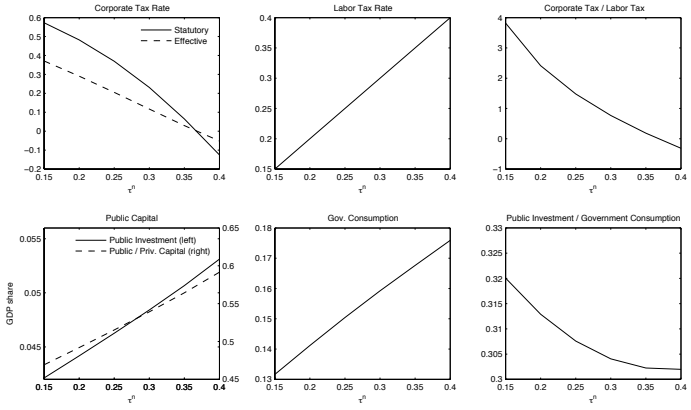


Figure B.2.7: Steady-state effects of exogenous changes in government consumption

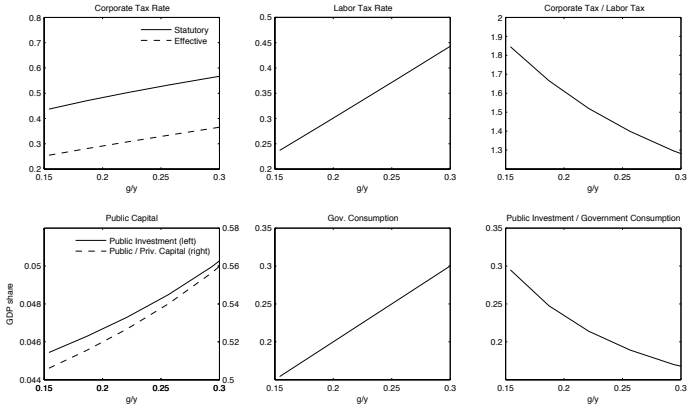
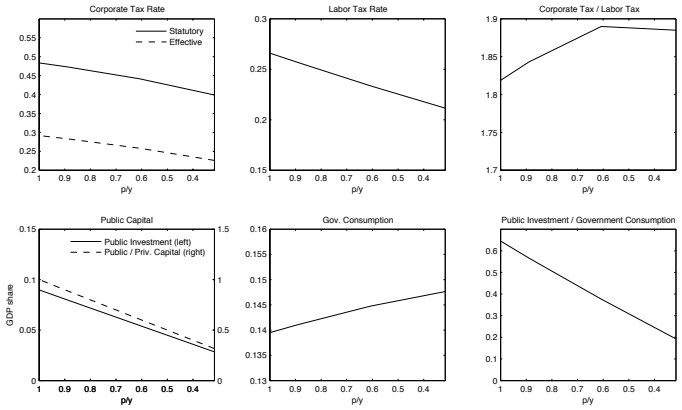


Figure B.2.8: Steady-state effects of exogenous changes in public investment



B.3 Disaggregated data on taxes and expenditures

Figure B.3.9: Taxes and allocation of public spending in the G7 countries (weighted by GDP)

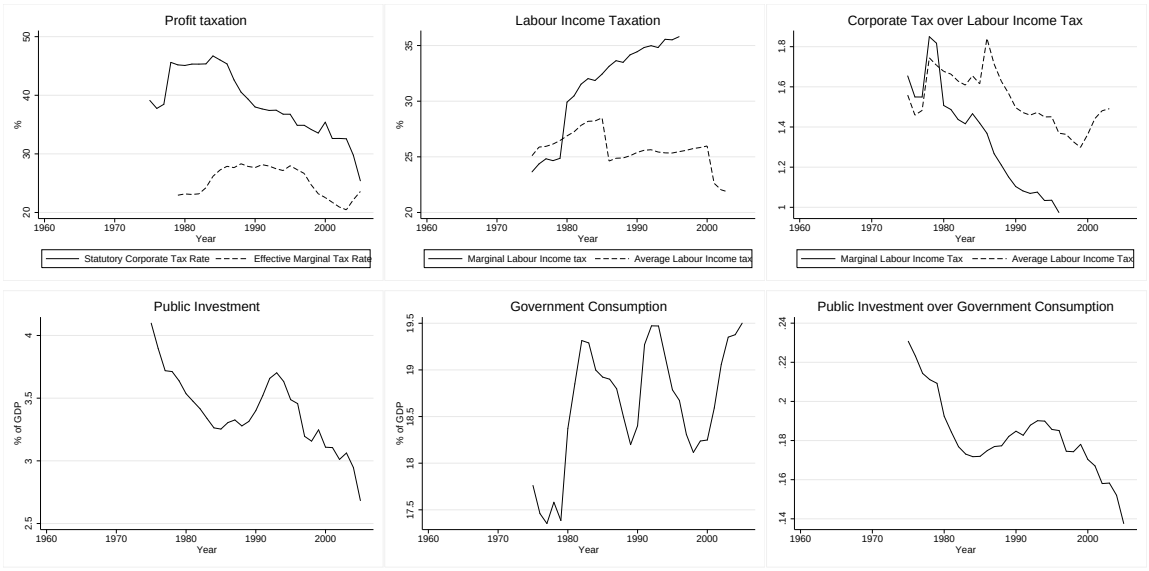


Figure B.3.10: Taxes and allocation of public spending in the G7 countries (weighted by population)

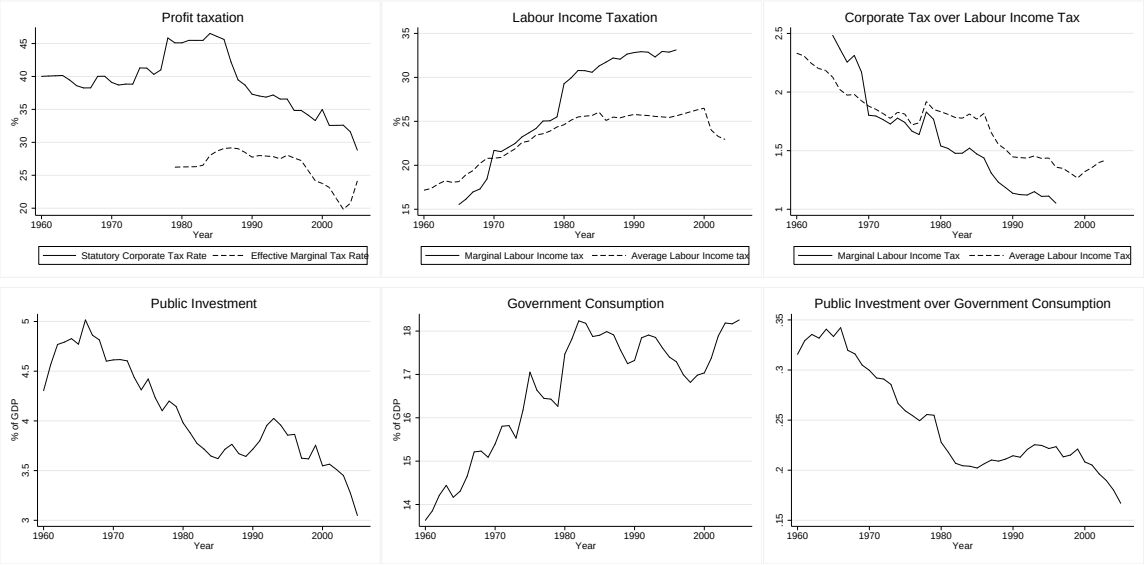


Figure B.3.11: Taxes and allocation of public spending in the OECD countries

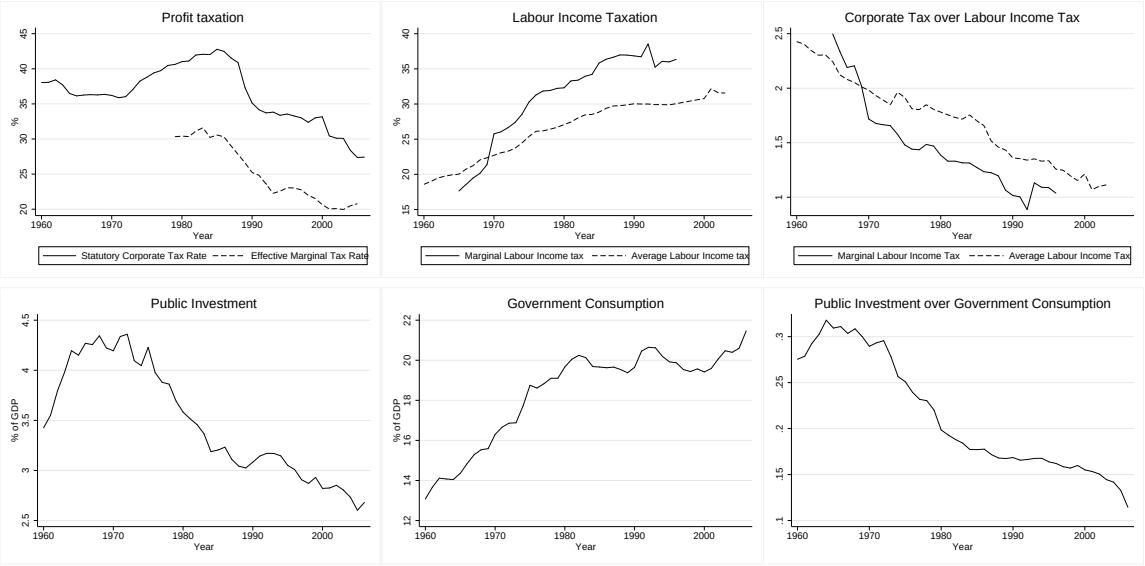
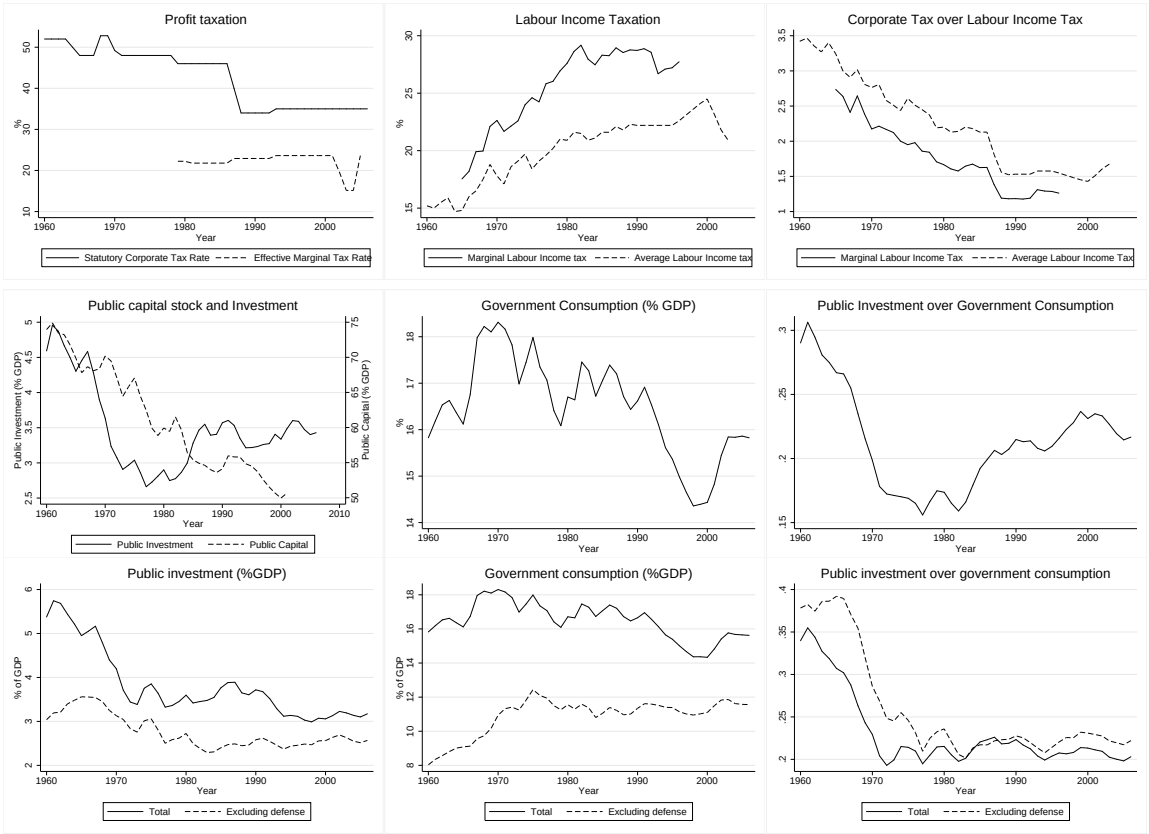


Figure B.3.12: Taxes and allocation of public spending in the US



Note: in the second row we use data from the OECD, while in the third row we use quarterly data from the NIPA tables (3.9.5). We exclude defence investment from total government investment.

Figure B.3.13: Taxes and allocation of public spending in Canada

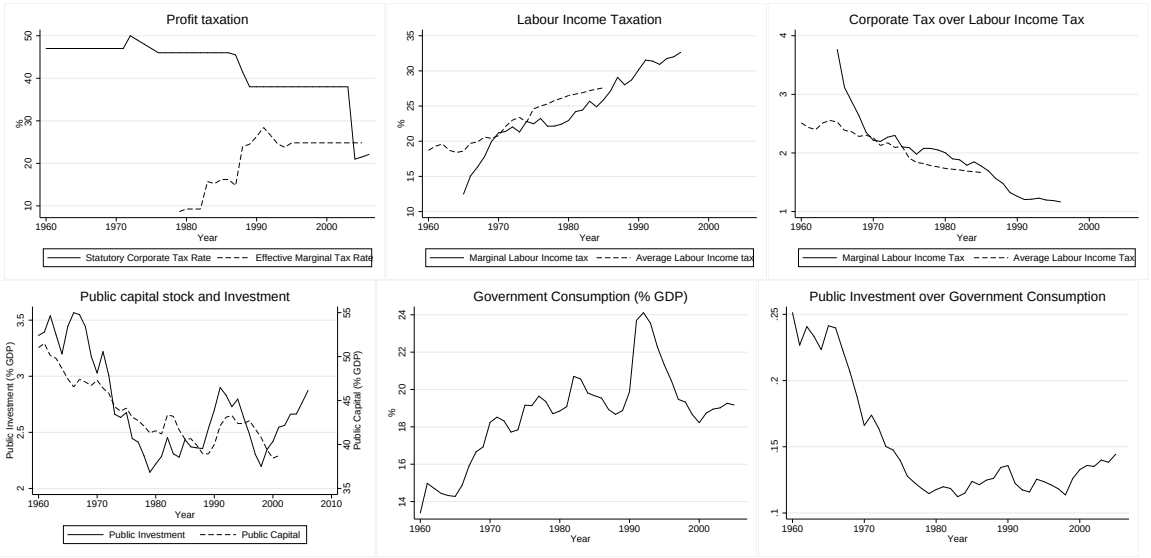


Figure B.3.14: Taxes and allocation of public spending in France

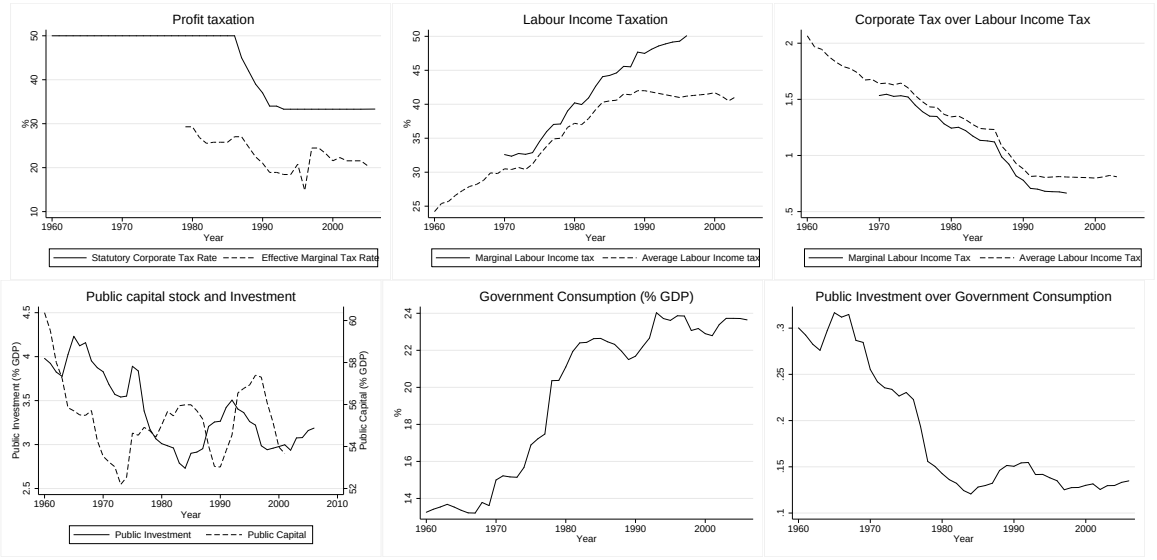


Figure B.3.15: Taxes and allocation of public spending in Germany

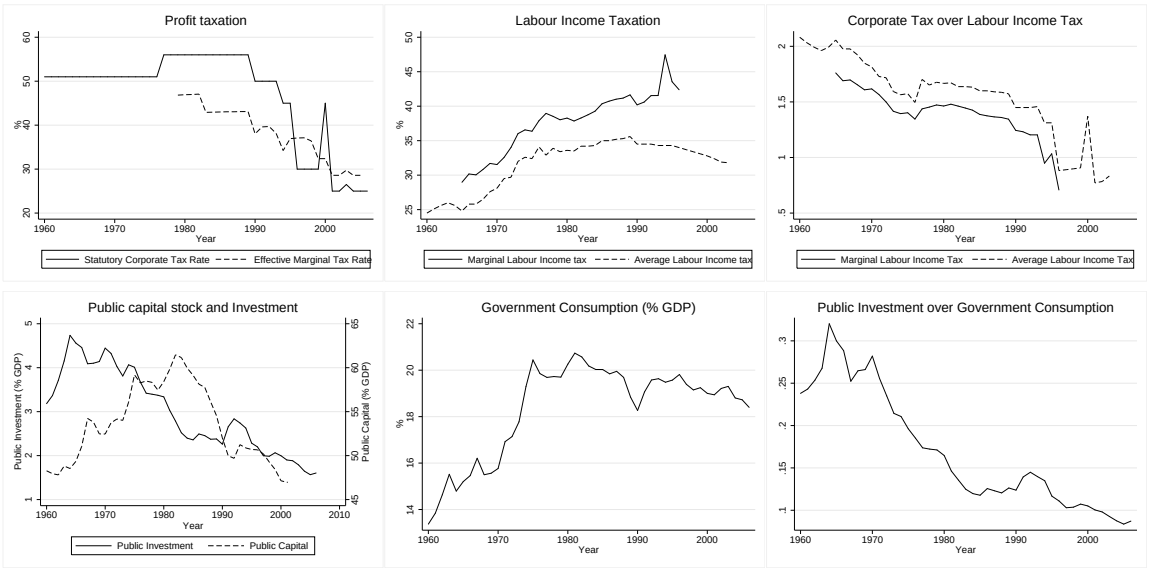


Figure B.3.16: Taxes and allocation of public spending in Italy

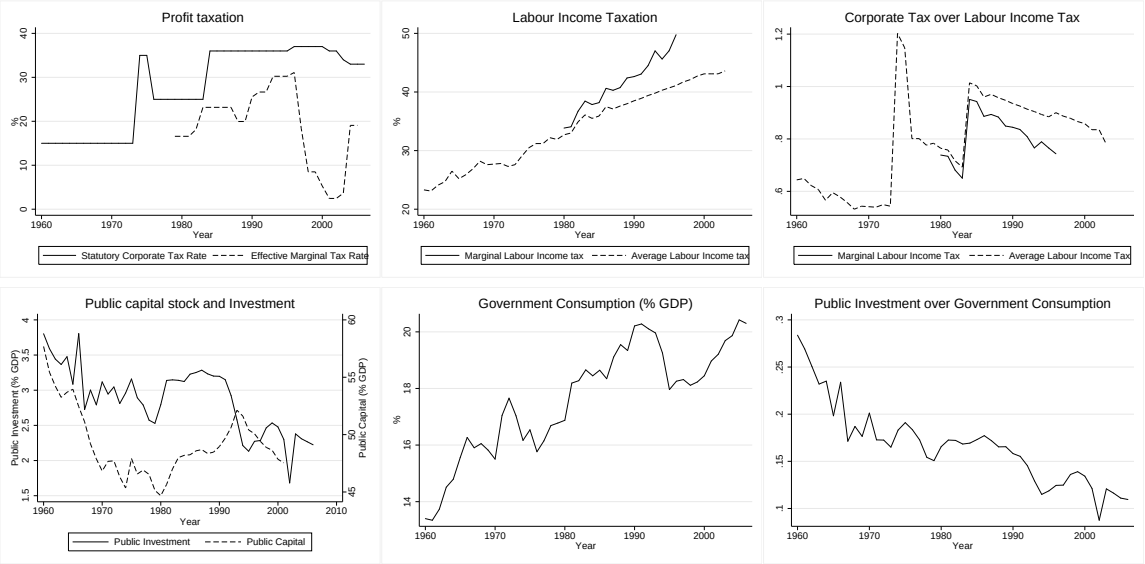


Figure B.3.17: Taxes and allocation of public spending in Japan

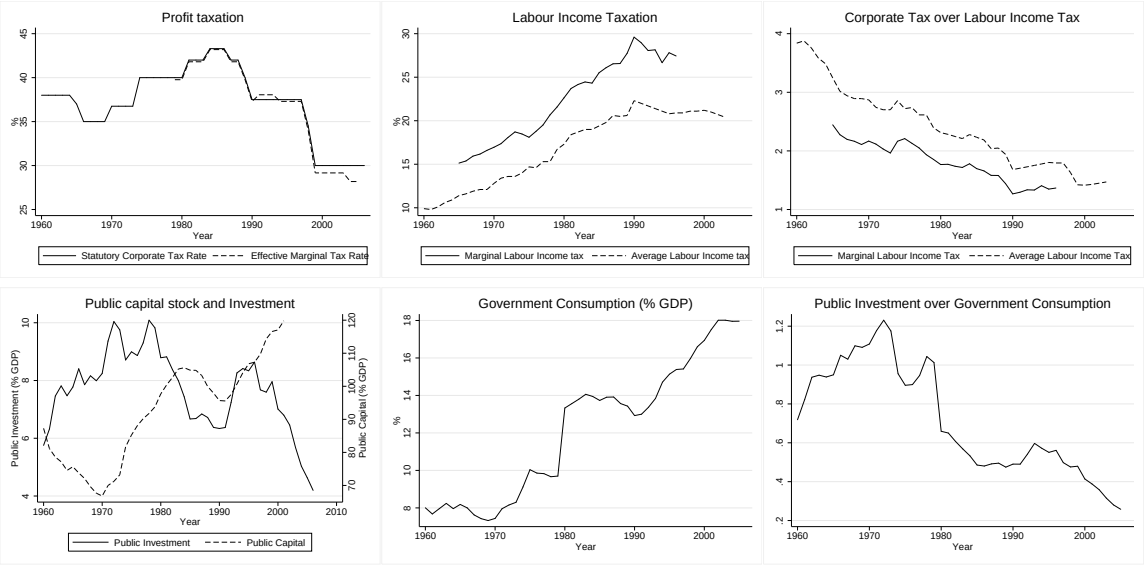


Figure B.3.18: Taxes and allocation of public spending in the UK