Optimal time–consistent taxation with international mobility of capital

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October 23, 2003

Abstract

The United States relies for its government revenues more on the taxation of capital relative to the taxation of labor than countries in continental Europe do. In this paper we ask what can account for this. Our approach is to look at Markov perfect equilibria of a two–country growth model where both governments use labor, capital and corporate taxes to finance exogenously given streams of public expenditure under period–by–period balanced budget constraints. There is no commitment technology and the equilibrium policies are time–consistent. We find that differences in productivity, size, and government spending can account for the heavy American reliance on capital taxation.

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1 Introduction

The United States and the United Kingdom rely more on the taxation of capital income relative to the taxation of labor income than their major European competitors do. Mendoza, Razin, and Tesar (1994) report that in the 1980:s the average capital income tax rates in the United States were about 42 percent and in the United Kingdom 57 percent. Corresponding numbers for France, Germany and Italy—the largest countries in continental Europe—were between 24 and 27 percent. At the same time, labor taxes were unambiguously higher in continental Europe. The average labor tax rates in France, Germany and Italy were, respectively, 40, 37 and 39 percent while in the United States and in the United Kingdom they were about 25 percent. These numbers have been updated and revised by Carey and Tchilinguirian (2000), and the overall pattern has not changed (For details, see Section 2.1).

There is considerable controversy concerning the measurement of tax rates, especially on capital, and it is perfectly reasonable to raise doubts about the proposition that the effective tax rate on capital income is higher in the United States than in continental Europe. Indeed, Gordon and Slemrod (1988) claimed that the U.S. government raises *no* significant revenue from the federal income tax.[1] However, there is no study that conducts an international comparison using the methodology of Gordon and Slemrod. Therefore, according to the available data that allows for an international comparison, there is no doubt that in the United states and the United Kingdom a larger *fraction* of general government revenue is accounted for by the taxation of assets. That is, these countries rely *relatively* more on the taxation of capital than on the taxation of labor than France, Germany and Italy do.

The purpose of this paper is to explore whether this difference in the structure of taxation can be explained by some of the differences in fundamentals between these two sets of countries. In particular, we explore the following factors: (i) The U.S. and the U.K. have lower government expenditures as a percentage of GDP; (ii) the economic size of the U.S. (but not the U.K.) is larger than each individual country in continental Europe. The difference in the size of the economy derives from both a larger population and a higher total factor productivity.

[1]This study ignored state and local taxes on capital income and property, and this is an important omission, since property taxes in the United States are mostly local. In any case, Gordon, Kalambokidis, and Slemrod (2003) assert that the U.S. government now *does* raise a significant amount of revenue from the federal income tax.

These differences are studied in a two–country open economy model in which (i) capital is internationally mobile (perfectly in the long run and imperfectly in the short run) but labor cannot move to the other country; (ii) governments can resort to corporate and personal capital income taxation, in addition to labor taxes;[2] (iii) they choose these taxes to maximize the welfare of their citizens but they are unable to commit to future policies. Within this modelling framework we show that both factors contribute to generate a higher taxation of capital income (relative to the taxation of labor income) in the U.S. than in continental Europe. Moreover, the first factor—higher government spending—also contributes to generating a higher taxation of capital in the U.K. than in continental Europe. More generally, we show that the government of a country with a lower government spending and a larger economy has an incentive to tax capital income proportionally more than labor income. The international mobility of capital is crucial for the second factor (the size of the economy) to have an impact on the taxation structure of a country while the first factor (government size) is important independently of the international mobility of capital. When we calibrate our model to capture the differences in these three dimensions between the U.S. (country 1) and continental Europe (country 2), we find that country 2 raises 13 percent of its government revenue through capital taxation. This is less than half the percentage of country 1. This *gap* between country 1 and country 2 is larger than in the data but captures the differential reliance on capital taxes between the United States and continental Europe.

To summarize, our main findings are the following. Countries that have a larger population size, are more productive and have smaller governments raise a larger fraction of revenues through the taxation of capital income.

The fact that in open economy settings the implications of government policies are affected by other governments actions has attracted the attention of economists for a long time. A survey can be found in Persson and Tabellini (1995). Most of the existing studies have analyzed the consequences of policy competition in non–quantitative simple theoretical settings without explicit attention to the situation in which the interacting countries differ from each other. By contrast, in this paper we explore the quantitative implications for the tax structure when countries are heterogeneous in government spending and size of the economy. A similar analysis is also conducted

[2]We abstract in this paper from consumption taxation. In homogenous agents models labor taxes and consumption taxes are quite similar along some dimensions and this creates computational problems: under some circumstances governments want to have huge consumption taxes and huge labor subsidies, while under not so different considerations, governments wants to do just the opposite. We leave for the future the explicit study of these issues.

in Ha and Sibert (1997) but in a model in which the supply of labor is exogenous and agents live for only two periods as in Kehoe (1989). The paper is also related to previous papers that study, in closed economy models, how inequality affects the voting preferences of agents and the endogenous determination of policies (Krusell, Quadrini, and Ríos-Rull (1996), Krusell, Quadrini, and Ríos-Rull (1997), Krusell and Ríos-Rull (1999)), and the optimal policy of benevolent governments (Klein and Ríos-Rull (2003)).

Unlike in some of the papers that we have cited, in our framework agents are infinitely lived, the supply of labor is endogenous, and capital is partially movable across countries. In addition, our model shares with the literature in optimal taxation the inability to tax existing wealth. This structure is, we think, the minimal needed to make the model suitable for calibration and for the analysis of the distortions induced by the equilibrium structure of taxation. Yet the combination of all these features result in an environment with five continuous, aggregate endogenous variables which makes very difficult the characterization of the solution with all but linear quadratic methods. This said our work has important limitations that future work will have to address. Perhaps the most important limitation is the restrictions of policies to have a period by period balanced budget constraint. Another important issue to consider is the existence of a wider set of taxes, especially consumption taxes.

The organization of the paper is as follows. Section 2 describes the main differences in government spending and taxation between the U.S and the European countries. After the presentation of these stylized facts, Section 3 describes the theoretical model and Section 4 defines the political equilibrium. Section 5 parameterizes the baseline economy characterized by two countries sharing the main macro aggregates of the U.S and Section 6 describes the equilibrium properties of the model. This section also performs a sensitivity analysis with respect to some of the parameters. In Section 7 we examine how the three differences between the U.S. and Europe affect the equilibrium taxes, both by looking at each of them in isolation and all them in unison. Section 8 concludes. The computational procedure is described in the Appendix.

2 Some key facts about the U.S. and Europe

2.1 Tax structure

According to the estimates of Mendoza, Razin, and Tesar (1994), in the 1980s the average capital income tax rate was about 42 percent in the United States and about 57 percent in the United Kingdom. Corresponding numbers for France, Germany and Italy—the largest countries in continental Europe—were between 24 and 27 percent. King and Fullerton (1984) reported more ambiguous numbers for the taxation of capital. According to them, Germany taxes capital at a rate in the range of 44 to 68 percent, the corresponding range for the United States being 32 to 49 percent.

Meanwhile, labor income is certainly taxed less in the United States than in Europe. Mendoza, Razin, and Tesar (1994) report rates close to 25 percent throughout the 1980's for the United States and the United Kingdom. The average labor tax rates in France, Germany and Italy are, respectively, 40, 37 and 39 percent.

Carey and Tchilinguirian (2000) update and revise the work of Mendoza, Razin, and Tesar (1994), and although the exact numbers are a bit different, the overall conclusions are not. The United States and the United Kingdom tax capital more, and labor less, than France, Italy and Germany do. See Tables 1 and 2.

An alternative approach is to infer differences in the effective capital income tax rates from observations on capital–output ratios. The idea is that, keeping constant preferences and technology, higher taxation of capital should lead to lower capital–output ratios. To do this properly, one would need other data as well (in particular, data on capital shares). But a first impression can be obtained from just comparing the capital-output ratios. As reported in Table 3, Italy and Germany have higher capital–output ratios than the United States and the United Kingdom. On the other hand, it appears that France has a lower capital–output ratio than the United Kingdom.

Some further evidence supporting the view that the United States and the United Kingdom rely *relatively* more on capital taxation than France, Italy and Germany comes from the OECD (2000) that reports tax revenue by tax base. According to this data, in the year 2000 the fraction of government revenue unambiguously attributable to the taxation of capital (i.e. taxes on personal capital gains, corporate income and property) was 23 percent in the United States, 22 percent in the United Kingdom, 7 percent in Germany, 12 percent in Italy and 13 percent in France. See Table 4. Unfortunately, taxes on personal capital and labor income are not reported separately and a more precise decomposition is not possible.

Table 1: **Average effective capital tax rates 1980-97.**

(a) Mendoza-Razin-Tesar method

Country	Tax rate
UK	58.3%
USA	39.9%
Italy	28.7%
France	27.3%
Germany	27.0%

(b) Carey-Tchilinguirian method

Country	Tax rate
UK	68.6%
USA	51.0%
Italy	49.6%
France	41.4%
Germany	36.4%

Source: Carey and Tchilinguirian (2000).

2.2 Government spending and size of the economy

Our candidates for explaining the relatively heavy American reliance on capital taxation are a lower government spending and a larger effective size of the economy. The first factor is also a candidate to explain the different taxation structure of the United Kingdom in comparison to the other European countries.

Table 2: **Average effective labor tax rates 1980-97.**

(a) Mendoza-Razin-Tesar method

Country	Tax rate
France	45.3%
Italy	42.7%
Germany	40.2%
USA	26.0%
UK	25.4%

(b) Carey-Tchilinguirian method

Country	Tax rate
France	40.2%
Italy	36.3%
Germany	35.9%
USA	22.6%
UK	21.0%

Source: Carey and Tchilinguirian (2000).

Government spending and total taxation Figure 1 plots total tax revenues and Figure 2 plots total government spending during the 1990:s. There are significant differences in government size between France, Germany and Italy on the one hand, and the United States and the United Kingdom on the other. While in the countries in continental Europe the size of the government is between 40 and 45 percent of GDP, in the U.S. and the U.K. government spending and taxation is in the order of 30–35 percent.

Size of the economy: As is well known, total GDP in the United States is much larger than the GDP of any European country. This is mainly determined by the differences in population size and in total factor productivity. The population of Germany (West plus East) is about 32 percent of that of the United States. The populations of France, Italy and the U.K., individually

Figure 1: Tax revenues as a percentage of GDP

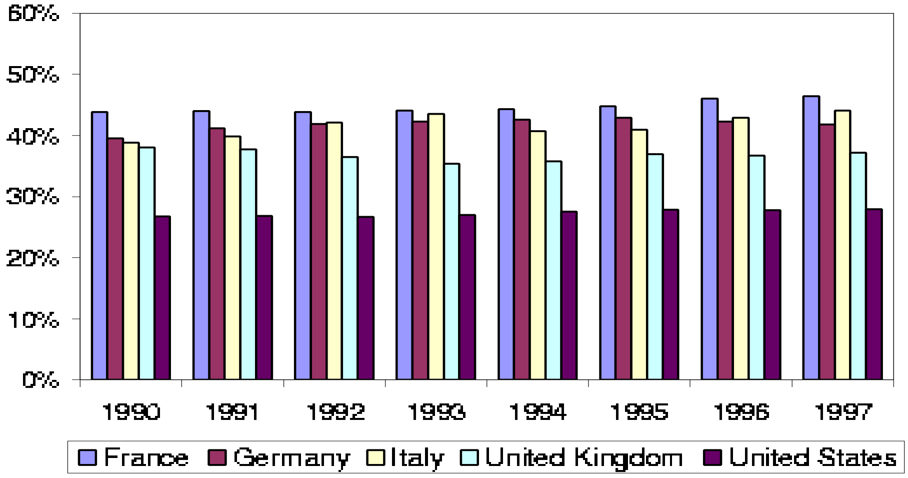

Figure 2: Government spending as a percentage of GDP

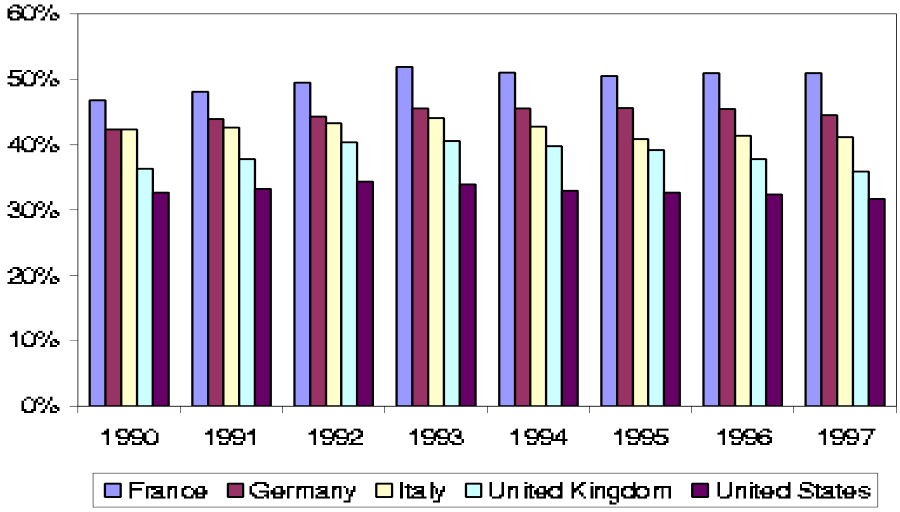

Table 3: **Capital–output ratios, 1996**

Country	Capital–output ratio
Italy	3.3
Germany†	2.8
UK	2.6
France	2.3
USA	2.2

† *Western Germany, 1994.*
Sources: OECD (1997a) and OECD (1997b).

Table 4: **Fraction of government revenue attributable to taxes on assets, 2000**

Country	Fraction
USA	22.6%
UK	22.3%
France	13.8%
Italy	11.9%
Germany	7.1%

Revenue from taxes on personal capital gains, corporate income and property divided by total government revenue. Source: OECD (2000).

considered, are about 23 percent of that of the United States.

By productivity we do not mean GDP per capita. Rather, what we have in mind is total factor productivity. We measure it by using OECD data on GDP, hours worked and the capital stock in each country. Under the assumption of a Cobb–Douglas production function for all countries, we find that in 1990 total factor productivity in Germany is 98 percent of that of the United States, with Italy and especially France lagging behind at 94 and 80 percent, respectively. The numbers for 1980 are similar, with Italy achieving 99 percent of the total factor productivity of the United States, Germany 91 percent and France only 81 percent. It is safe to conclude that the United States is more productive than its major European competitors.

3 The Economic Model

The model is a two–country, $i \in \{1, 2\}$, neoclassical growth model extended to include a government sector with distortionary taxation, and imperfect within-period capital mobility. The government of each country faces the problem of optimally financing an exogenous stream of public spending without being able to commit to policy plans for the future. We start describing the model given certain policy rules followed by the governments. Afterwards, we describe how these policy rules are determined. A crucial element of this environment is that governments cannot commit to future policies. We will be looking for time consistent Markov policies, rather than the time inconsistent Ramsey policies.

Preferences: In each country there is a continuum of consumers of total mass μ_i with standard preferences over streams of consumption and leisure. The consumer's objective is $\sum_t \beta^t\, u(c_{it}, h_{it})$, where c_{it} and h_{it} are consumption and hours worked in country i at time t. Households cannot change their country of residence, which makes labor immobile.

Production Possibilities: In each country there is a standard neoclassical technology represented by the production functions $F_i(Y_{it}, L_{it})$. The variable Y_{it} is the amount of capital *used* in country i, and L_{it} is the total number of efficiency units of labor used in country i. Note that technologies can differ across the two countries which justifies the index i in the production function.

The output of each country is perfectly mobile which implies the following worldwide feasibility constraint:

$$\sum_{i=1,2} \mu_i \left(C_{it} + I_{it} + G_{it}\right) = \sum_{i=1,2} \mu_i F_i \left(Y_{it}, L_{it}\right) \tag{1}$$

where C_{it} is consumption, I_{it} investment, and G_{it} government purchases in country i. All variables are expressed in per capita terms. The law of motion for the capital stock is

$$K_{it} = (1 - \delta)Y_{it} + I_{it} \tag{2}$$

where K_{it} is the capital that is installed in country i at the beginning of the next period and δ is the depreciation rate.

The reason for denoting by K_{it} the beginning of next period's installed capital, and by Y_{it} the capital effectively used, is that capital is imperfectly mobile across countries within a period. There is a technology that shuffles capital at a cost. This technology can be written as $\mathcal{M}(K_{1t-1}, K_{2t-1}, Y_{1t}, Y_{2t}) = 0$. We can interpret the implicit function $\mathcal{M}$ as stating which combinations of usable capital $\{Y_{1t}, Y_{2t}\}$ are possible starting with installed capital $\{K_{1,t-1}, K_{2,t-1}\}$. Not changing installed capital is obviously feasible, *i.e.*, $\mathcal{M}(K_{1t-1}, K_{2t-1}, K_{1t-1}, K_{2t-1}) = 0$. We assume that the implicit function $\mathcal{M}$ is homogeneous of degree zero (it displays constant returns to scale) and it is strictly convex to reflect increasing adjustment costs. Given these properties, we write the re-installation technology more compactly as $M(x, y_1, y_2) = 0$, where y_1 and y_2 denotes capital rented in countries 1 and 2 respectively by a firm that owns one unit of capital and that has a fraction x of this unit initially allocated in country 1 and a fraction $1-x$ allocated in country 2. This technology will give the government some power to tax installed capital, but this power is limited since capital could flee. Figure 3 shows the typical shape of the M function for a situation where half the capital is installed in each country.

The presence of this friction matters in a deterministic steady state, even though no actual shuffling takes place in equilibrium. The point is that taxes are set depending on how capital *would* move if taxes changed somewhat.

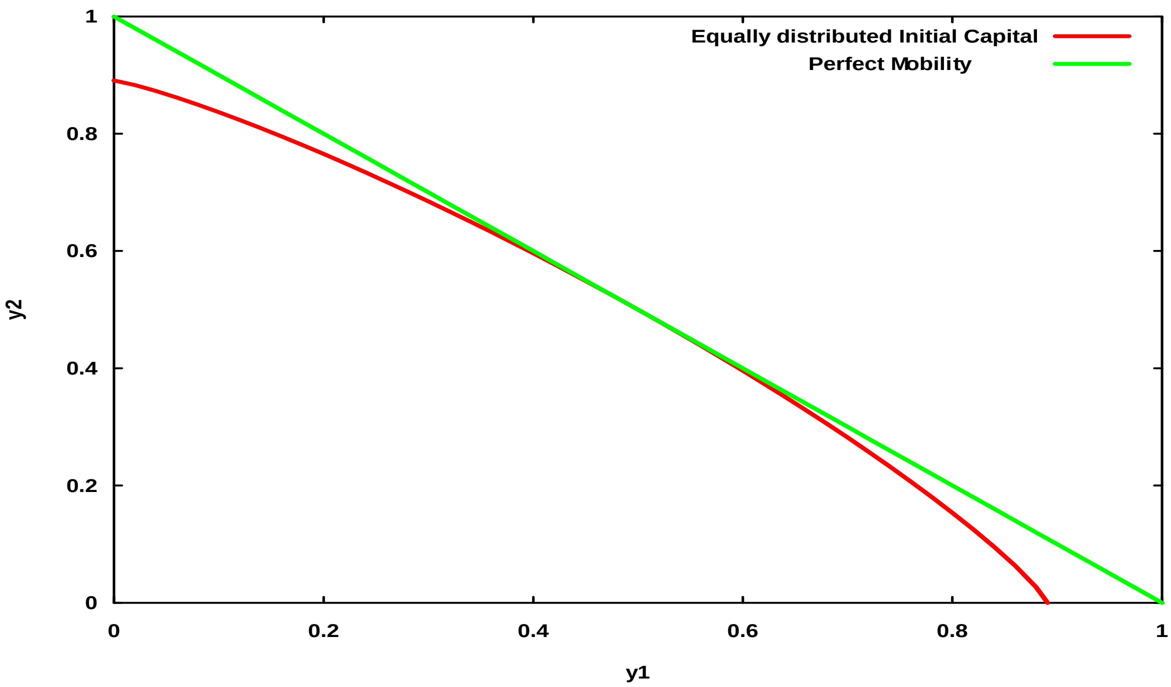

Figure 3: Capital Mobility, $M(x, y_1, y_2) = x^{-\gamma}\, y_1^{1+\gamma} + (1-x)^{-\gamma}\, y_2^{1+\gamma} - 1$, $x = .5$, $\gamma = .2$

We refer to the firms that buy and install capital and later may reallocate it as investment firms. We refer to the firms that operate the production technologies as production firms. Notice that the former face a dynamic problem (where to install the capital) while the problem faced by the latter is static.[3]

The Government: Public expenditures are composed of government purchases, denoted by G_i, and government transfers, denoted by T_i. These variables are exogenous in the model and they are constant over time. To finance public expenditures, the governments of the two countries tax capital rents paid by firms at rate ζ_{it}, capital income received by households at rate θ_{it} and labor income at rate τ_{it}. The taxation of capital rents includes all taxes that are paid on the non-labor income generated by the firm. Corporate taxes are part of this form of taxation and in the rest of the paper we simply refer to ζ_{it} as the corporate tax rate. It should be remembered, however, that this tax includes all forms of capital income taxation, not only corporate taxes, based on the location of the production factor (source principle) as opposed to the residency of the recipients (residence principle). The main difference between the corporate tax rate, ζ_{it}, and the capital income tax rate, θ_{it}, is that the first is paid by the firm, while the second is paid by the households. Without international mobility of capital the two forms of taxation would be economically indistinguishable. With international mobility of capital, however, they have different economic consequences: if a country relies heavily on foreign capital, the corporate tax is a more effective source of tax revenue than the capital income tax as some of the capital income generated by domestic firms is paid to foreign residents.

In each period the government chooses the *current* labor and corporate income tax rates and the *next period* capital income tax rate. Therefore, the current capital income tax rate is inherited from the previous period while the current corporate and labor tax rates are decided in the current period. The one-period commitment to the capital income tax rate is necessary to prevent an excessive taxation of capital income received by households. This is because households' income from capital (and households' wealth) can be taxed without distortions in the current period. This is in line with the optimal taxation literature (Chari, Christiano, and Kehoe (1994), Judd (1987), Klein and Ríos-Rull (2003), Stockman (2001)). This is not necessary, however, for corporate taxes because the mobility of capital discourages the two governments from excessively taxing the

[3]Alternatively, we could assume that households directly decide where to allocate the capital, without the need of the investment firm. The properties of the model would be equivalent.

capital income generated by domestic firms (households cannot change their residency but they can reallocate their assets in the foreign country through the investment firms).

Governments in both countries are subject to a period by period balance budget constraint, that is,

$$G_i + T_i = \zeta_i \,(p_i - \delta)\, Y_i + \tau_i \, w_i \, H_i + \theta_i \, r \, A_i, \qquad i = 1, 2. \tag{3}$$

where p_i are the capital rents paid by domestic firms per unit of rented capital, Y_i the total units of rented capital, w_i the wage rate, H_i the aggregate labor supply, r the unit return of households' wealth and A_i the aggregate households' wealth.

Notice that we rule out consumption taxes. In one–country settings, the role of consumption taxes have been studied under commitment in Coleman (2000) and without commitment in Krusell, Quadrini, and Ríos-Rull (1996).

4 Recursive representation and policy equilibrium

The analysis is limited to Markov stationary policy rules, where a policy rule is a function that returns the current labor and corporate tax rates and the next period capital income tax rates for both countries, as a function of the current states of the economy. We will denote this function by $\varphi(S)$, where S is the vector of aggregate states.

The aggregate state variables include the per capita wealth held by the households of the two countries, A_1 and A_2, the aggregation of which is equal to the total amount of capital installed in both countries. Moving capital is costly, so another aggregate variable is needed to describe how much capital is installed in each country. We will use the variable X to denote the fraction of worldwide capital that is installed in country 1. Finally, the economy inherits capital income tax rates as the governments set this rate in advance. Therefore, $S = \{\theta_1, \theta_2, A_1, A_2, X\}$.

The main goal of this section is to define a policy rule $\varphi(S)$ that is time–consistent (governments do not have an incentive to deviate from this rule) when the two governments choose their policy instruments (tax rates) independently on a competitive basis. This requires three steps. The first step (Section 4.1) defines the economic equilibrium for arbitrary policy rules φ. This step is important because allows us to determine the welfare levels of the two countries for arbitrary future policy rules. The second step (Section 4.2) defines the optimal equilibrium tax rates in the current period when future tax rates are determined by some arbitrary policy rule. Because the optimal current tax rates depend on the current states, this step defines the optimal *current* policy rule, given *future* rules. Finally, the third step (Section 4.3) defines the conditions for which the governments will not deviate from the rules assumed for the future (time–consistency). This will be the case if the policy rule assumed for the future is equal to the rule that is optimal in the current period (policy fixed point).

4.1 Step 1: Equilibrium for arbitrary policy rules

Assume that the tax rates in the two countries are determined by an arbitrary function φ, that is, $(\tau_1, \zeta_1, \theta_1, \tau_2, \zeta_2, \theta_2) = \varphi(S)$. Once this function is specified, the agents' problems are well defined. Following is the description of the problems.

The households' problem: We define the household's problem recursively. The state variables for the household are the aggregate states as defined above plus its own wealth that we denote by a (individual state). The dynamic programming problem is:

$$\begin{aligned}
V_i(S,a;\varphi) &= \max_{c,h,a'} u(c,h) + \beta V_i\left(S',a';\varphi\right) && (4)\\
\text{s.t.} & && \\
c &= (1-\tau_i)\ w_i\ h + (1 + r\,(1-\theta_i))\,a + T_i - a' && (5)\\
r &= r(S;\varphi) && (6)\\
w_i &= w_i(S;\varphi) && (7)\\
\tau_i &= \varphi_{\tau,i}(S) && (8)\\
\theta_j' &= \varphi_{\theta,j}(S) \qquad \text{for } j=1,2 && (9)\\
A_j' &= \Phi_{A,j}(S;\varphi) \qquad \text{for } j=1,2 && (10)\\
X' &= \Phi_X(S;\varphi) && (11)
\end{aligned}$$

where w_i is the wage rate in country i and r is the rate of return on its assets. The functions $\Phi_{A,j}$ and Φ_X define the law of motion for the aggregate states A_j and X.

The solution for this problem is given by the working hours, $h = g_{h,i}(S,a;\varphi)$, and the next period claims to the capital of the investment firms, $a' = g_{a,i}(S,a;\varphi)$. Obviously, this problem can only be solved once the functions in equations (6)-(11) are specified. Note that we are indexing these equations with policy functions φ. We do so to be explicit about the fact that they are equilibrium functions. Once we know these functions, the agent's decision rules can be characterized by the following first order conditions:

$$-u_h(c,h) = w_i(1-\tau_i)\, u_c(c,h) \tag{12}$$
$$u_c(c,h) = \beta(1+r(1-\theta_i))\, u_c(c',h') \tag{13}$$

The investment firms' problem: For an investment firm, the individual state variables are given by the total stock of capital they invested in the previous periods and the location (in country 1 and 2) of this capital. We use the pair (k, x) to denote the individual states of the investment firm, where k is the capital owned by the firm and x the fraction of this capital initially installed in country 1.

Given the initial location of the owned capital, x, the firm decides how to change this location. At the end of the period, the firm returns all the proceeds to the shareholders. Therefore, there are two stages in which the firm makes decisions. At the end of each period it decides where to allocate the new capital between the two countries. At this stage, the firm has full flexibility in choosing the location of its investment (installation). At the beginning of the next period, starting with this allocation of capital, the firm decides how to reallocate it. At this stage, the reallocation of capital is not completely flexible but it depends on the technology M.

Given the constant-return-to-scale property of the investment technology, the choices of the investment firm are independent of its scale. Therefore, without loss of generality, we consider the problem of a firm that owns (has purchased) one unit of capital. Let's start with the problem solved at the beginning of the period, when the firm starts with the allocation x. Let $\Omega(S, x; \varphi)$ be the value of such a firm. The value of a firm with k units of capital is simply given by $k \cdot \Omega(S, x; \varphi)$. The problem that this firm solves is:

$$\Omega(S,x;\varphi) = \max_{\{y_1,y_2\}} \sum_{i=1,2} \Big[1 + (p_i(S;\varphi) - \delta)(1-\zeta_i)\Big] y_i \tag{14}$$

$$\text{s.t.} \qquad M(x, y_1, y_2) = 0 \tag{15}$$

where p_i is the rental rate of capital in country i. These rents are considered profits in country i

and they are taxed at rate ζ_i. The first order conditions of this problem yield:

$$\frac{1+[p_1(S;\varphi)-\delta](1-\zeta_1)}{1+[p_2(S;\varphi)-\delta](1-\zeta_2)} = \frac{M_2(x,y_1,y_2)}{M_3(x,y_1,y_2)} \tag{16}$$

where M_2 and M_3 are the derivatives of function M with respect to their second and third arguments respectively. Given the constraint $M(x,y_1,y_2)=0$, the first order conditions give the pair of solution functions for the allocation of capital $\{g_{y,j}(S,x;\varphi)\}_{j=1,2}$.

Taking into consideration this reallocation policy that will be implemented in the next period, the investment firm decides today where to install the new capital. Formally

$$\max_{x'} \ \Omega(S',x';\varphi) \tag{17}$$
$$\text{s.t.} \qquad S' = (\varphi_\theta(S), \Phi_A(S;\varphi), \Phi_X(S;\varphi)) \tag{18}$$

with solution $x' = g_x(S;\varphi)$.

Notice that in this non-stochastic environment, the initial allocation of capital is always equal to the next period allocation because the investment firms perfectly forecast the future. This would not be case in the presence of shocks.

The ex-post household's return from owning one share (one unit of capital) of the investment firm is simply given by $1+r' = \Omega(S', g_x(S;\varphi);\varphi)$.

Production firms' problem: Production firms of each country solve a static problem. They rent capital and hire labor to maximize the following profit function:

$$\max_{y,h} \ F_i(y,h) - p_i(S;\varphi)\, y - w_i(S;\varphi)\, h \tag{19}$$

The first order conditions for these firms are:

$$p_i(S;\varphi) = \frac{\partial}{\partial y} F_i(y,h) \tag{20}$$
$$w_i(S;\varphi) = \frac{\partial}{\partial h} F_i(y,h) \tag{21}$$

Notice that free entry guarantees that profits are zero and these two expressions define the equilibrium prices p_i and w_i.

Equilibrium: We are now in a condition to define an equilibrium.

Definition 1 *A Recursive competitive equilibrium for given policies φ is a list of aggregate functions $\{\{\Phi_{Y,i}, \Phi_{H,i}, p_i, w_i, \Phi_{A,i}\}_{i=1,2}, \Phi_X, r\}$, household values and decision rules, firms values and decisions so that:*

(i) Factor prices are marginal productivities in each country,

$$p_i(S;\varphi) \;=\; \frac{\partial}{\partial Y_i} F_i\left[\Phi_{Y,i}(S;\varphi), \Phi_{H,i}(S;\varphi)\right] \qquad i=1,2, \tag{22}$$

$$w_i(S;\varphi) \;=\; \frac{\partial}{\partial H_i} F_i[\Phi_{Y,i}(S;\varphi), \Phi_{H,i}(S;\varphi)] \qquad i=1,2. \tag{23}$$

(ii) Households optimize and are representative,

$$g_{a,i}(S, A_i;\varphi) \;=\; \Phi_{A,i}(S;\varphi) \qquad i=1,2, \tag{24}$$

$$g_{h,i}(S, A_i;\varphi) \;=\; \Phi_{H,i}(S;\varphi) \qquad i=1,2. \tag{25}$$

(iii) Investment firms solve their problem and are representative,

$$\frac{M_2(\Phi_X(S;\varphi), \Phi_{Y,1}(S;\varphi), \Phi_{Y,2}(S;\varphi))}{M_3(\Phi_X(S;\varphi), \Phi_{Y,1}(S;\varphi), \Phi_{Y,2}(S;\varphi))} \;=\; \frac{1+(p_1(S;\varphi)-\delta)(1-\varphi_{\zeta,1}(S))}{1+(p_2(S;\varphi)-\delta)(1-\varphi_{\zeta,2}(S))} \tag{26}$$

$$M(\Phi_X(S;\varphi), \Phi_{Y,1}(S;\varphi), \Phi_{Y,2}(S;\varphi)) \;=\; 0, \tag{27}$$

$$g_x(S;\varphi) \;=\; \Phi_X(S;\varphi). \tag{28}$$

(iv) Both governments balance their budget every period. For $i \in \{1,2\}$,

$$\begin{aligned} G_i + T_i \;=\; & \varphi_{\zeta,i}(S)\,(p_i(S;\varphi)-\delta)\,\Phi_{Y,i}(S;\varphi) \;+ \\ & \varphi_{\tau,i}(S)\,w_i(S;\varphi)\,\Phi_{H,i}(S;\varphi) + \theta_i\,r(S;\varphi)\,A_i \end{aligned} \tag{29}$$

Conditions *(i)* and *(ii)* are standard. Condition *(iii)* requires some further explanation. It has three parts and all of them are implications of the fact that under constant returns to scale in the investment sector what firms consider optimal is what the economy as a whole does. The first and second parts, equations (26) and (27), state that what the economy as a whole allocate as capital in each country has to satisfy the first order conditions of the firms that make that decision. The third part, equation (28) states that what an investment firm considers to be an optimal allocation rule of new investment, is also what the whole economy chooses as an allocation rule. Condition *(iv)* is obvious.

4.2 Step 2: Optimal Current Policy Rule for Given Next Period Policy Rule

Governments take as given the function that determine future policies—the function φ—and the other country's current policies $\{\zeta_{i^*}, \tau_{i^*}, \theta'_{i^*}\}$. The star denotes the other country variable. We first start defining an equilibrium for arbitrary policies today (again policies that are feasible) while assuming that next period the policies revert to those implied by φ. Let's use π as a compact notation for an arbitrary current policy, that is, $\pi = \{\pi_1, \pi_2\} = \{\zeta_1, \tau_1, \theta'_1, \zeta_2, \tau_2, \theta'_2\}$. These policies are determined through a strategic game that the two governments play with each other. We limit the analysis to perfect Markov equilibria.

In order to determine the equilibrium policies, we start looking at the problem solved by individual households when the two governments choose arbitrary policies π in the current period and future policies will be determined by some policy function φ. The next period value functions are the value functions for the problem with given policy functions φ as defined in the previous section. For the current period, instead, the value functions are indexed by the arbitrary current policies π. We denote all functions that are affected by the arbitrary policies π with hats. We then have:

$$\hat{V}_i(S,\pi,a;\varphi) = \max_{c,h,a'} u(c,h) + \beta V_i(S',a';\varphi) \tag{30}$$

s.t.

$$c = (1-\tau_i)\ w_i\ h + [1 + r(1-\theta_i)]\,a + T_i - a' \tag{31}$$

$$r = \hat{r}(S,\pi;\varphi) \tag{32}$$

$$w_i = \hat{w}_i(S,\pi;\varphi) \tag{33}$$

$$\tau_i = \pi_{\tau_i} \tag{34}$$

$$\theta'_j = \pi_{\theta'_j} \qquad \text{for } j = 1,2 \tag{35}$$

$$A'_j = \hat{\Phi}_{A,j}(S,\pi;\varphi) \qquad \text{for } i = 1,2 \tag{36}$$

$$X' = \hat{\Phi}_X(S,\pi;\varphi) \tag{37}$$

with solution $a' = \hat{g}_{a,i}(S,\pi,a;\varphi)$ and $h = \hat{g}_{h,i}(S,a,\pi;\varphi)$.

The problem solved by the investment firm is similar to the problem solved in the previous section. The solutions are denoted by $\{\hat{y}_i(S,\pi;\varphi)\}_{i=1,2}$ and $\hat{x}'(S,\pi;\varphi)$.

We now describe the hat equilibria.

Definition 2 *A recursive equilibria for arbitrary policy actions π this period followed by policy functions φ is a list of aggregate functions $\{\{\hat{\Phi}_{Y,i}, \hat{\Phi}_{H,i}, \hat{p}_i, \hat{w}_i, \hat{\Phi}_{A,i}\}_{i=1,2}, \hat{\Phi}_X, \hat{r}\}$, household values and decision rules, firms values and decisions so that:*

(i) Factor prices are marginal productivities in each country,

$$\hat{p}_i(S,\pi;\varphi) = \frac{\partial}{\partial Y_i} F_i\left(\hat{\Phi}_{Y,i}(S,\pi;\varphi), \hat{\Phi}_{H,i}(S,\pi;\varphi)\right) \qquad i = 1,2, \tag{38}$$

$$\hat{w}_i(S,\pi;\varphi) = \frac{\partial}{\partial H_i} F_i\left(\hat{\Phi}_{Y,i}(S,\pi;\varphi), \hat{\Phi}_{H,i}(S,\pi;\varphi)\right) \qquad i = 1,2. \tag{39}$$

(ii) Households are representative,

$$\begin{aligned}\hat{g}_{a,i}(S,\pi,A_i;\varphi) &= \hat{\Phi}_{A,i}(S,\pi;\varphi) \qquad i=1,2, \qquad (40)\\ \hat{g}_{h,i}(S,\pi,A_i;\varphi) &= \hat{\Phi}_{H,i}(S,\pi;\varphi) \qquad i=1,2. \qquad (41)\end{aligned}$$

(iii) Investment firms solve their problem and are representative,

$$\frac{M_2(\hat{\Phi}_X(S,\pi;\varphi),\hat{\Phi}_{Y,1}(S,\pi;\varphi),\hat{\Phi}_{Y,2}(S,\pi;\varphi))}{M_3(\hat{\Phi}_X(S,\pi;\varphi),\hat{\Phi}_{Y,1}(S,\pi;\varphi),\hat{\Phi}_{Y,2}(S,\pi;\varphi))} = \frac{1+(\hat{p}_1(S,\pi;\varphi)-\delta)(1-\pi_{\zeta_1})}{1+(\hat{p}_2(S,\pi;\varphi)-\delta)(1-\pi_{\zeta_2})} \qquad (42)$$

$$M(\hat{\Phi}_X(S,\pi;\varphi),\hat{\Phi}_{Y,1}(S,\pi;\varphi),\hat{\Phi}_{Y,2}(S,\pi;\varphi)) = 0, \qquad (43)$$

$$\hat{g}_x(S,\pi;\varphi) = \hat{\Phi}_X(S,\pi;\varphi). \qquad (44)$$

(iv) The governments balance their budget every period, that is, for $i \in \{1,2\}$,

$$\begin{aligned}G_i + T_i &= \zeta_i(\pi)\,(\hat{p}_i(S,\pi;\varphi)-\delta)\,\hat{\Phi}_{Y,i}(S,\pi;\varphi) + \qquad (45)\\ &\quad \tau_i(\pi)\,\hat{w}_i(S,\pi;\varphi)\,\hat{\Phi}_{H,i}(S,\pi;\varphi) + \theta_i\,\hat{r}(S,\pi;\varphi)\,A_i\end{aligned}$$

The derivation of the functions $\hat{V}_i$ allows us to define the current return for the governments from a policy π_i. The maximization of this return will then define the optimal current policy. Let

$$\mathbf{V}_i(S,\pi_i,\pi_{i^*};\varphi) = \hat{V}_i(S,\pi_i,\pi_{i^*},A_i;\varphi) \qquad (46)$$

Both governments choose π_i simultaneously to maximize $\mathbf{V}_i$. We then have the following definition.

Definition 3 *Given the function φ, a Nash equilibrium of the policy game is a pair of functions $\{\pi_i(S;\varphi)\}_{i=1,2}$ such that $\pi_i(S;\varphi)$ maximizes $\mathbf{V}_i(S,\pi_i,\pi_{i^*};\varphi)$ given $\pi_{i^*}(S;\varphi)$.*

4.3 Step 3: The Policy Fixed Point

We now have all the elements required to define the equilibrium time-consistent policies.

Definition 4 *We say that the policy function φ defines the time-consistent policies if it is the Nash solution of the policy game when the governments expect φ to determine future policies. Formally*

$$\varphi_i(S) = \pi_i(S; \varphi) \qquad i = 1, 2. \tag{47}$$

5 The baseline model economy

In this section we describe the equilibrium properties of the tax rates for what we label the baseline model. This is a case of two identical countries (symmetry) that are similar to the U.S. These countries inherit capital income tax rates from the previous period and set simultaneously labor and corporate income taxes. We start describing the functional forms in Section 5.1 and we go on with the calibration details in Section 5.2.

5.1 Functional forms

We start choosing functional forms. We choose a utility function of the form

$$u(c, h) = \frac{c^{1-\sigma_c}}{1-\sigma_c} + \alpha \frac{(\ell - h)^{1-\sigma_h}}{1-\sigma_h}. \tag{48}$$

where ℓ is the total available working time. This utility function is not standard in the study of business cycles. It is being increasingly used however when authors care about response of hours to wages. For example Castañeda, Díaz-Giménez, and Ríos-Rull (2002), choose this utility function to ensure that the cross-sectional distribution of hours generates a reasonable profile, given the properties of the wage process and the tax system. This functional form is convenient because it allows us to vary the elasticity of hours worked. Production takes place according to a Cobb-Douglas technology, so that output in country i, at time t, is $\lambda_i Y_{it}^{\eta} L_{it}^{1-\eta}$.

We assume that the technology to reallocate capital takes the normalized form:

$$M(x, y_1, y_2) = x^{-\gamma}\, y_1^{1+\gamma} + (1-x)^{-\gamma}\, y_2^{1+\gamma} - 1 \tag{49}$$

Notice that if $\gamma = 0$, then capital can be shifted across countries without cost, which implies perfect mobility of capital. The higher the value of $\gamma > 0$, the more costly is to move capital internationally. Therefore, we will refer to γ as the parameter of capital mobility. A graphical representation of this function is provided in Figure 3.

5.2 Calibration targets and parameterization

We assume that policies are chosen every two years which determines the length of a period in the model. We do this as a compromise between the time between elections and the administrative length over which government budgets are defined. It also agrees with the political cycle of several countries.

The calibration targets for the baseline model economy are listed in Table 5. These targets refers to the U.S. economy and some comments are warranted. We want to get a narrow notion of capital which corresponds not as much with total wealth but with taxable capital generating income. We choose a low elasticity of substitution of labor which is not very different from the one estimated by Castañeda, Díaz-Giménez, and Ríos-Rull (2002). The degree of risk aversion that we impose is quite standard, just a little bit more than the logarithmic case. We choose the size of government in the baseline model economy to be half way between the U.S. (outlays are 27% of GDP, 15% of expenditures and 12% of transfers) and Europe (we choose 18% of expenditures and 22% of transfers totaling 40% of GDP). We target a share of government revenue coming from capital income sources to one third, the value reported by Carey and Tchilinguirian (2000). We choose the units in which we measure time within a period so that the amount of working time is around one.[4]

Table 6 reports the parameter values for the baseline model with symmetric countries. They all seem standard to us. Perhaps one parameter value that deserves a comment is the capital reallocation parameter, $\gamma = 0.003$. This means that, if we are in a symmetric situation with $x = 0.5$ and we reallocate 20% of the of the capital installed in country 1 to country 2, then 19.988% of this capital becomes available in country 2.

Since no capital is actually reallocated it is not clear how to assess this number. While we could think of many mechanisms that permit low reallocation costs (intensity of use, reshuffling of parts over time and maintainance to say a few), we just restate that its value is the result of the calibration process.

[4]It turns out that this choice avoids computational problems that have shown up when we use other normalization process.

We will conduct some sensitivity analysis for all the non standard dimensions of the calibrated model—specifically, the degree of capital mobility, the length of the period, the elasticity of labor and the composition of government expenditures.

Table 5: **Calibration Targets for the baseline economy (annual base).**

Rate of return	0.07
Investment to GDP Ratio	0.15
Capital Share of output	0.30
Fraction of time worked	0.40
Elasticity of hours worked	0.75
Government purchases to GDP Ratio	0.165
Government transfers to GDP Ratio	0.17
Capital Taxes/Total Revenues in the U.S.	0.333
Time per period	3.20
Length of policy reassessment	Two years

Table 6: **Calibration values for the baseline economy (annual base).**

Discount rate	β	0.976
Utility parameter	σ_c	1.500
Utility parameter	σ_h	2.000
Utility parameter	α	2.080
Utility parameter	ℓ	3.200
Capital share	η	0.300
Depreciation rate	δ	0.076
Capital mobility parameter	γ	0.003

6 Properties of the baseline model and sensitivity analysis

In this section we first describe the quantitative properties of the baseline model and we conduct a sensitivity analysis with respect to some key parameters. The sensitivity analysis will be helpful to understand some of the factors that are important in answering the questions addressed in the paper.

6.1 The baseline model economy

The first row of table 7 reports the steady state result for the baseline economy with two identical countries. Labor income is taxed at a lower rate than capital income. This is especially noteworthy given that capital income is taxed twice. Once with corporate taxes when it is generated (source principle) and then with capital taxes when it is paid to consumers (residence principle). Even though it is taxed at a lower rate, the share size of labor income (the size of the tax base) ensures that a larger fraction of revenues comes from labor taxes.

6.2 Sensitivity analysis

We report the findings of the sensitivity analysis in Table 7 where we look at alternative values for the degree of capital mobility, the length of the period, the leisure-consumption elasticity and the size of the government. Some of our choices are limited by the fact that sometimes we have had trouble computing the equilibrium, in particular this is the case when labor is quite elastic.

6.2.1 The degree of capital mobility

We look at values of the mobility parameter of $\gamma = 0$ and $\gamma = .02$, compared to a value of $\gamma = .003$ for the baseline model economy. We see that small changes to the cost have large implications for the corporate tax. (Recall that the mobility cost is very small in the baseline model.) The qualitative properties are obvious: the easier it is to take the capital abroad, the lower the corporate tax rate. Note that to offset partially the larger corporate taxes, capital income taxes are lower the less mobile is capital. The budget balanced requirement imposes a logical adjustment on the labor income tax. Notice that perfect mobility of capital, ($\gamma = 0$), does *not* lead to zero corporate taxes. The reason is that, although taxing profits repels capital the movement of capital to the other country reduces its return in the other country which prevents a large outflow of capital. This would not be the case if the country were a small open economy. At the same time, in the current period capital income taxes are given. Therefore, lower corporate taxes requires higher taxation of labor which is distortionary. In this respect the endogeneity of labor plays an important role. With exogenous labor supply as in Ha and Sibert (1997), competition would lead to zero corporate taxes (at least in the case of symmetric countries).

Table 7: **Baseline Economy and Sensitivity Analysis.**

Departure from Baseline	Capital Tax, θ	Corporate Tax, ζ	Labor Tax, τ	$\frac{\text{Capital Taxes}}{\text{Total Revenue}}$
Baseline	**55.8%**	**19.9%**	**34.3%**	**28.4%**
Capital mobility				
$\gamma = 0.00$	56.6%	17.4%	34.4%	28.0%
$\gamma = 0.02$	50.5%	33.3%	33.3%	30.5%
Length of period				
One and a half years	65.7%	15.7%	31.6%	34.0%
Four years	27.5%	30.3%	38.8%	18.9%
Elasticity of labor				
$\sigma_h = 1.7$	52.1%	23.1%	34.8%	27.2%
$\sigma_h = 2.3$	57.4%	18.1%	34.1%	28.8%
Composition of expenditures				
$\frac{G}{GDP} = 0.135$, $\frac{T}{GDP} = 0.200$	55.3%	20.5%	34.3%	28.3%
$\frac{G}{GDP} = 0.195$, $\frac{T}{GDP} = 0.140$	56.3%	19.4%	34.2%	28.5%

6.2.2 The length of the period

The second experiment relates to the length of the period which is a form of commitment: the longer the period, the later in the future the new capital income taxes will be implemented. As can be seen from the table, a decrease in the political cycle or length of governmental commitment induces a very large increase in the capital income tax rate. This property of the model is also present in other analysis of government policy (see Krusell and Ríos-Rull (1999) and Klein and Ríos-Rull (2003)) and it has a simple intuition.

6.2.3 The elasticity of substitution of hours worked

The third experiment consists of changing the value of the parameter σ_h. In changing σ_h we also change the parameter α so that the steady state hours worked do not change under constant taxes. A more elastic labor supply (larger values of σ_h) increases the corporate tax rate because labor taxes become more distortionary. In fact, when labor is very elastic, an increase in the labor tax rate induces a large fall in the labor supply and a large fall in the productivity of capital. This in turn will induce an outflow of capital. Therefore, the government prefers higher corporate taxes. In setting the capital income tax rate, the government anticipates that future corporate taxes will be higher and to prevent an excessive taxation of capital it decreases θ'. The increase in corporate taxes is almost compensated by the reduction in capital income taxes so that the whole taxation of capital does not change substantially.

6.2.4 Composition of the government outlays

The last change is with respect to the composition of government outlays. In the first of the two experiments the countries have much larger transfers and consequently smaller government expenditures, while in the second experiment the structure of outlays is the opposite. As shown in the bottom section of Table 7, the change in the composition of government expenditures has only a marginal impact on the equilibrium tax structure.

7 U.S. versus Europe

As discussed in Section 2, capital income taxes are higher in the U.S. than in continental Europe. In this section we ask whether the different taxation structure between the U.S. and Europe can be explained by some economic differences between the two sets of countries or regions. To be able to do this, we need a theory of what makes Europe different from the U.S. A theory that has widespread support does not exist. Hence, we base our discussion on a small set of observables that can be taken to be exogenous and that are clearly different between the two sets of countries (and one also consistent with the differences between the U.K. and continental Europe). These differences are that the U.S. has a smaller government (relative to the size of the economy) and a larger economy (compared to each of the European countries). Specifically, we modify the baseline model to incorporate these features that differentiate the two areas.

Before proceeding, we would like to point out a noteworthy theoretical feature of the model. A steady state equilibrium requires that the capital income tax rate is the same in the two countries, otherwise the citizens of the two countries would save at different rates. If they save at different rates, the world distribution of capital will change, meaning that the equilibrium cannot be a steady state. However, when countries are heterogeneous, their governments may have different incentives to tax capital. These incentives depend on how the ownership of world capital is distributed, that is, they depend on A_1 and A_2. This implies that in a steady state equilibrium the world distribution of wealth must be such that the two governments have the same incentive to tax capital. This also implies that the world distribution of wealth in a steady state equilibrium may differ from the distribution of capital among the productive units of the two countries, that is, $K_i \neq A_i$. Therefore, in searching for a steady state equilibrium we search for the steady state ratio A_1/K_1 or A_2/K_2 for which the two countries tax capital income at the same rate.

In what follows there is the analysis of the steady state equilibria associated with each of the two types of heterogeneity between the U.S. and Europe.

7.1 Government size

The public sector is larger in Europe than in the U.S. Conservative measures of the size of the government in each country yield that government taxation is about 27 percent of GDP in the U.S. and about 40 percent of GDP in the three major countries in continental Europe. Therefore, we assume that in country 1 government expenditures are 27 percent while in country 2 they are 40 percent. The equilibrium tax rates are reported in Table 8. The country with a larger government sector (country 2) has both higher corporate taxes and much higher labor taxes. What is important is that the second country has a larger fraction of revenue deriving from labor taxes. Therefore, countries with larger government sectors, like the European countries, tend to tax labor more than capital.

The reason why a large government (in relation to GDP) raises a higher proportion of its revenue through the taxation of labor income is that the burden function associated with the capital tax is more convex than the burden function associated with the labor tax. In an equilibrium where governments optimize, marginal burdens are equalized across taxes. It follows that a rise in total revenue will be associated with a shrinking share of revenue raised by the tax associated with the

Table 8: **Differences in Government Size:** $\frac{G_1+T_1}{GDP_1} = .27$, $\frac{G_2+T_2}{GDP_2} = .40$.

	Capital Tax, θ	Corporate Tax, ζ	Labor Tax, τ	$\frac{\text{Capital Taxes}}{\text{Total Revenue}}$	$\frac{K}{A}$
Country 1	53.0%	13.7%	26.7%	30.7%	97.8%
Country 2	53.0%	27.2%	43.3%	24.2%	102.8%

more convex burden function.[5]

The last column of Table 8 reports the ratio between the capital used in the country and the assets of the country. If this ratio is smaller than one then the country is a net exporter of capital. This is the case for country 1: because of the higher corporate taxes, some of the domestic assets are invested abroad.

7.2 The size of the economy: population and productivity

During much of its recent history, the U.S. has had a centralized tax authority while Europe consists of a relative large number of countries. Therefore, we consider the case in which country 1 (the U.S.) has a larger population than country 2 (individual European country). Table 9 reports the steady state values when the population of country 1 is four times the population of country 2 (country 1 has 4/5 of the world population). This is the population of the United States relative to the average population of the three largest countries in continental Europe individually considered (France, Germany and Italy).

As explained above, the capital income tax rates are the same in both countries. However,

[5]A burden function maps revenue raised by a tax into the welfare cost imposed; at the peak of the Laffer curve, the slope of the burden function is infinite, since a non–vanishing increase in the burden is associated with a vanishing increase in revenue. When all taxes are zero, the slope of each burden function is 1, since the marginal excess burden is zero. Thus a burden function is convex; its slope is increasing. Since capital income is a smaller tax base than labor income, the Laffer curve peaks at a lower level of revenue for capital taxes than for labor taxes. That means that the slope of the burden function goes faster to infinity, and is therefore more convex.

Table 9: **Differences in Population Size. Country 1 has 4/5 of the world's population.**

	Capital Tax, θ	Corporate Tax, ζ	Labor Tax, τ	$\frac{\text{Capital Taxes}}{\text{Total Revenue}}$	$\frac{K}{A}$
Country 1	47.7%	40.0%	32.2%	32.7%	94.9%
Country 2	47.7%	16.0%	38.7%	19.2%	121.0%

corporate taxes are much higher in the larger country. This is consistent with the notion that if a country is large, then it is less concerned about capital flight. The rest of the world is small and capital outflow is limited by the decreasing returns abroad induced by these flows.

Table 10: **Differences in Total Factor Productivity:** $\lambda_1 = 1$, $\lambda_2 = .9$.

	Capital Tax, θ	Corporate Tax, ζ	Labor Tax, τ	$\frac{\text{Capital Taxes}}{\text{Total Revenue}}$	$\frac{K}{A}$
Country 1	56.1%	20.6%	34.0%	29.0%	99.0%
Country 2	56.1%	18.8%	34.5%	27.9%	101.1%

To capture the productivity differential (output per hour) between the U.S. and Europe, we assume that the total factor productivity of country 2 is 10 percent smaller than country 1, that is, $\lambda_1 = 1.0$ and $\lambda_2 = 0.9$. Table 10 shows that the more productive country (country 1) taxes more heavily corporate profits. This is because the more productive country has a larger economy and is less concerned about capital flight as in the case of a country that has a larger population. As a result of the higher incentive to tax corporate profits, the fraction of revenues deriving from the whole taxation of capital is higher in the more productive country.

7.3 All differences combined

We now consider the case in which all the above differences are combined together. In particular, the second country has a larger government, a smaller population and a lower productivity. Ideally we would like to calibrate the model to the U.S. and Europe. This is a not trivial task for two reasons. First, Europe is not composed of homogeneous countries. Second, the U.S. and Europe also interact with other countries with different degrees of integration. Therefore, in assigning the parameter values, some abstraction and compromise have to be made. Taking into consideration these difficulties, we make the same calibration choices we made above in considering each of the individual differences. More specifically: (i) Government expenditures are 27 percent of GDP in country 1 and 40 percent in country 2. As claimed above, these numbers are approximately the averages for the United States and the largest countries in continental Europe (France, Germany, Italy); (ii) The population of country 2 is 25% the population of country 1 ($\mu = 0.25$); (iii) Total factor productivity of country 2 is 90% the total factor productivity of country 1 ($\lambda_2 = 0.9$).

The results are reported in Table 11. As expected from the previous analysis, the combination of the three features that differentiate the U.S. from the European countries induce a much lower taxation of capital in country 2. In this country (Europe) the fraction of revenue deriving from the taxation of capital is 13.4 percent while in country 1 (the U.S.) this is 33.3%. This *gap* between country 1 and country 2 is larger than in the data but captures the differential reliance on capital taxes between the United States and continental Europe.[6]

There is another feature of the model that we would like to emphasize. As a result of the higher taxation of labor, hours worked are smaller in the second country. In the calibrated model, agents in country 1 work 5% more than agents in country 2. This is consistent with the data on working hours in the U.S. and the major countries in continental Europe. Finally, we observe in the last column of Table 11 that the first country is a net exporter of capital. This is also consistent with the fact that the United States is a net exporter of capital (at least until the last few years).

[6]Based on numbers from Carey and Tchilinguirian (2000), during the 1990s the fraction of revenue from the taxation of capital was 33% in the U.S. and 23% in the three major countries in continental Europe. Although we have chosen γ to replicate the first number, we have not chosen any other parameter to get the second number.

Table 11: **Countries heterogeneous in government spending, population and productivity. Model calibrated to the U.S. and Europe.**

	Capital Tax, θ	Corporate Tax, ζ	Labor Tax, τ	$\frac{\text{Capital Taxes}}{\text{Total Revenue}}$	$\frac{K}{A}$
Country 1	39.1%	37.9%	25.7%	33.3%	95.8%
Country 2	39.1%	18.0%	49.5%	13.4%	122.1%

8 Conclusions

This paper has studied the equilibrium tax policies in a two-country model with international mobility of capital. The analysis of several differences among countries allowed us to study the possible factors that may account for the different taxation structure between the U.S. and continental Europe. We found that differences in public spending and the size of the economy (population and productivity) may account for the higher capital taxation (and lower labor taxes) of the U.S. relative to continental Europe. Differences in public spending can also explain why the taxation structure in the United Kingdom is more similar to the United States than to the other European countries. An additional feature of our model is the prediction that hours worked are lower in the country identified as Europe—which is consistent with the data.

Thus we have identified one possible reason for why the U.S. relies relatively more on capital taxation than continental Europe does. There may of course be others. Mateos-Planas (2003) considers the role of demography. He finds that the relative reliance on capital taxation in the U.S. has fallen over time, and that much of this shift can be accounted for by changes in the age composition of the population. This suggests that demographic factors might play a role in accounting for trans–Atlantic differences, as well. A careful study of this issue would be a useful complement to our analysis.

Important considerations for future research, in addition to the consideration of a diverse population (both in terms of demographics and in earnings and wealth), are the explicit consideration of a larger set of policy instruments. These include consumption taxes, but perhaps more importantly, it also includes the ability of governments to issue debt.

A Computational procedure

In this paper we compute only steady states equilibria, that is equilibria in which all variables, including the tax rates, remain constant over time. Still, since government's actions can affect the whole equilibrium path, the quantitative characterization of the steady state requires the computation of the decision rules out of the steady state. We characterize these rules using a local approximation procedure. Global methods are in general preferable. However, because our economy has five state variables, the use of global methods is not practical. The computational procedure combines the basic linear-quadratic approximation method with a policy iteration procedure that follows the steps used in Section 4 to define a policy equilibrium.[7]

For given (constant) tax rates, there is a multiplicity of steady state equilibria, each characterized by a particular wealth ratio A_1/A_2. However, there is only one ratio A_1/A_2 for which the two governments choose the same tax rates on the personal capital income, that is, $\theta_1 = \theta_2$. Although we have not proved the inexistence of multiple equilibria, we did not find any such instance. Therefore, our procedure starts by guessing the steady state tax rates, with the imposition of $\theta_1 = \theta_2$, and a guess for the steady state wealth ratio A_1/A_2. We then check whether the two governments have an incentive to deviate from these rates when they solve the strategic game. The details of the computational steps are as follows.

1. We guess the steady state tax rates $\pi_i = (\zeta_i, \theta_i)$ for $i = 1, 2$ and the steady state wealth ratio A_1/A_2. The tax rates on labor τ_i will be determined residually by the budget constraints for the governments.

2. Given the steady state tax rates and the wealth ratio we can solve for all the other steady state variables using the first order conditions to the agents' problem (equations (12) and (13)) and the government's budget constraints.

3. We approximate the utility functions of the representative agents in both countries with a second order Taylor expansion around the steady state values calculated in the step above and based on the guessed steady state tax rates and wealth ratio.

4. We guess policy rules $\varphi = (\varphi_1, \varphi_2)$ for the current corporate taxes and for the next period capital taxes as linear functions of the aggregate states. The states are given by the per-capita wealth held

[7]Klein, Krusell, and Ríos-Rull (2002) use a second order approximation to solve a similar model with only one country and find that the computational improvement is very small; the errors in tax rates are less than half a percentage point.

by the households of the two countries, the fraction of worldwide capital installed in country 1, and the capital income tax rates inherited from the previous period.

5. Given the policy rules, the agents' problem is well defined and we can derive the households' value functions $V_i(S, a; \varphi)$, as defined in (4), through value function iteration. Given the quadratic form of the approximated return functions, $V_i(S, a; \varphi)$ is also quadratic.

6. Given the functions $V_i(S, a; \varphi)$, we construct the (quadratic) functions $\hat{V}_i(S, \pi, a; \varphi)$ as defined in (30). After imposing the aggregate consistency conditions $a = A_i$, we take the first order conditions with respect to π_1 for country 1 and with respect to π_2 for country 2. This gives the (linear) reaction functions for each of the two countries.

7. By solving the two reaction functions with respect to π_1 and π_2, we find the current policy rules as functions of the states, that is, $\pi = \pi(S; \varphi)$.

8. The functions $\pi(S; \varphi)$ are then used to update the guess for the policy functions φ. The procedure is then restarted from step 5 until policy convergence, that is, $\varphi(S) = \pi(S; \varphi)$.

9. At this point we check whether the policy function $\varphi(S)$—when evaluated at the steady state values—reproduces the steady state tax rates guessed at the beginning of the procedure (step 1). The fact that the policy rule reproduces the guessed tax rates means that the two governments have no incentives to deviate from these tax rates. Therefore, they are the equilibrium steady state taxes. If the derived policy function does not replicate the guessed tax rates, we restart the procedure from step 1 using a different guess for the tax rates and the wealth ratio. The difference between the personal capital income taxes chosen by the two governments instructs us on how to update the guess for the wealth ratio. For example, if country 1 chooses higher θ than country 2, we decrease A_1/A_2. We continue the process until the policy function replicates our guess for the steady state tax rates.

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