Policy commitment and the welfare gains from capital market liberalization

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First Version: September 2000

This Version: February 2004

Abstract

This paper evaluates the quantitative impact of capital liberalization on the taxation structure and welfare of the liberalizing countries when governments conduct fiscal policy optimally but without commitment (time-consistent policies). The transition from a regime of capital autarky to a regime of free mobility leads to a decrease in the long-term tax rate on capital of 13 percent and an increase in the tax rate on labor of 2 percent. As a consequence of this taxation shift, welfare increases by about 1 percent. The reduction in capital taxation induced by capital market liberalization is welfare improving because, in the absence of capital mobility, the time-consistent policies over-tax capital.

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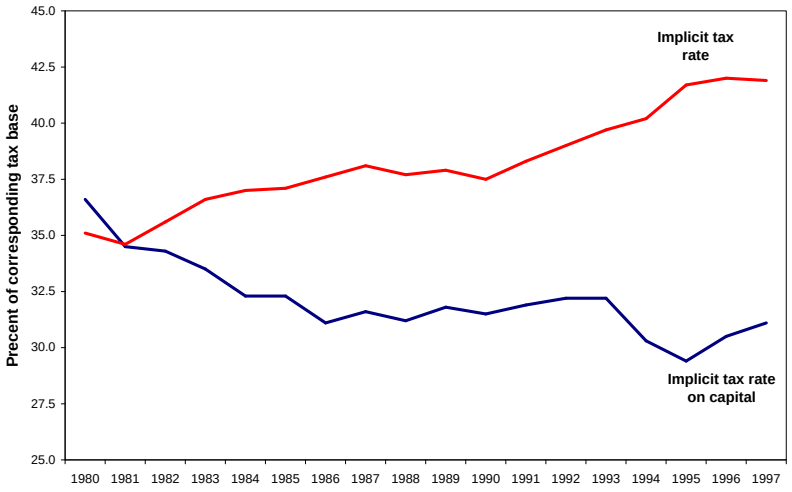
*I would like to thank Hilary Appel, Thomas Cooley, Jason Cummins, Per Krusell, Jonathan Heathcote, Víctor Ríos-Rull and Akos Valentinyi for helpful comments. Send correspondence to: Vincenzo Quadrini, Department of Finance and Business Economics, Marshall School of Business, 701 Exposition Boulevard, Los Angeles, CA 90089. e-mail: quadrini@usc.edu

1 Introduction

One of the heated debates in international economics concerns the liberalization of capital markets. A central theme within this debate is the issue of tax policy coordination. It has been argued that, given the fiscal policy autonomy of countries and the increase in the international mobility of capital, policy competition may lead to distortionary tax policies. Indeed, the incentive to attract foreign capital and prevent capital outflow may induce countries to shift the taxation burden from the highly mobile capital to the less mobile labor force. For instance, a shift in the taxation structure is observed in the integration experience of the European countries. As shown in figure 1, during the 1980s and the 1990s the implicit tax rate on capital has been decreasing while the implicit tax rate on labor has been increasing.[1]

Figure 1: Implicit tax rates on capital and labor in the European Union



Source: Eurostat, Structure of the taxation systems in the European Union 1970-1997, 2000 edition.

There are reasons to believe that this taxation shift is, at least in part, the consequence of the increasing tax competition among European countries following the gradual removal

[1]The implicit tax rate is defined as the ratio between the tax revenue and the tax base.

of barriers to the mobility of capital. This shift in the tax structure is a major concern among European authorities. For example, in the October 1997 communication from the European Commission to the European Council, the Commission concludes: "*...This trend in tax structure should be reversed*". Concerns about harmful tax competition, given the globalization of capital markets, are also expressed by the Organization for Economic Cooperation and Development (see OECD (1998)). These concerns are consistent with the empirical study of Devereux, Lockwood, & Redoano (2002) who find that OECD countries do in fact compete over corporate taxes.

The goal of this paper is to develop and calibrate a two-country open-economy model to evaluate the quantitative impact of capital liberalization on the taxation structure and the welfare of the liberalizing countries. In the model governments finance exogenous public spending with three types of taxes: a profit tax, a capital income tax, and a labor income tax, under a balanced budget constraint. The difference between the profit tax and the capital income tax relates to the unit of taxation. While the profit tax is paid by firms to the country where they are located (source principle), the capital income tax is paid by the residents of the country independently of whether the income stems from domestic or foreign investment (residence principle). Without the international mobility of capital, the profit tax and the capital income tax would be economically indistinguishable. Governments choose the three tax rates optimally to maximize the welfare of their citizens on a period-by-period basis (time-consistent policies). In characterizing the equilibrium tax policies I restrict the set of strategies played by the two governments to be Markov and the analysis is limited to Markov perfect equilibria.

Using this framework the paper shows that, in the absence of tax coordination, capital liberalization leads to: (a) a reduction in the implicit tax rate on capital of 13 percent; (b) an increase in the tax rate on labor of 2 percent; (c) a 1 percent improvement in welfare.

These results suggest that the free mobility of capital is the optimal arrangement given the international setting. A corollary to this result is that fiscal policy competition is Pareto superior to policy coordination. This is because the equilibrium with coordinated policies is equivalent to the equilibrium without the mobility of capital.

These results depend crucially on the assumption that the two governments decide their policies on a period-by-period basis and they cannot commit to future policies (time-consistency). As shown in the optimal taxation literature[2], in a short time horizon the taxation of capital is less distortionary than the taxation of labor. If the policy maker could commit to long-term policy plans, it would minimize the taxation of capital in the long-run. However, in absence of commitment, the long-term plan is time-inconsistent. Since in a short horizon the taxation of capital is weakly distortionary, the period-by-period optimization implies that the policy maker will tax capital incomes heavily, not only in the current period, but also in future periods, which is inefficient. The international mobility of capital reduces the incentive to tax capital since this capital may seek out more favorable conditions abroad. This implies that the equilibrium taxation of capital is lower and the welfare of the representative consumer higher. The threat of capital flight compensates for the lack of policy commitment.

The result that capital liberalization may improve welfare by reducing the taxation of capital is not new in the literature. Patrick Kehoe (1989) showed in a simple two-period model that tax coordination may lead to over-taxation of capital and lower welfare. A similar result is also discussed in Persson & Tabellini (1995). Although the theoretical results are not new, the quantitative impact of capital liberalization (or tax competition) are unknown. One of the contributions of this paper is to study the consequences of

[2]See Benhabib & Rustichini (1997), Chamley (1986), Chari, Christiano, & Kehoe (1994), Judd (1987), Jones, Manuelli, & Rossi (1993), Klein & Rios-Rull (1999), Zhu (1992)

capital liberalization quantitatively.[3]

A second contribution of the paper is to study the effects of capital liberalization in a more general framework than in the previous literature. For example, the model studied in Kehoe (1989) has only two periods and the inputs of capital and labor are not complementary in production. This latter feature leads to the result that the equilibrium tax rate on capital, in absence of coordination, is always zero. In contrast, the current paper studies optimal tax policies in an infinite horizon model with capital and labor complementary in production. Due to the complementarity, the equilibrium taxation of capital is also positive in the non-cooperative equilibrium with mobility. The equilibrium taxes with capital mobility is also studied in Ha & Sibert (1997). In their model, however, agents live only for two periods (overlapping of generations) and the supply of labor is inelastic. This latter feature implies that profit taxes are zero when countries are symmetric. The more general structure of the model used in the current paper (infinite horizon and elastic labor supply) makes it suitable to address quantitative questions.

The paper also evaluates the welfare consequences of capital liberalization more specifically for Europe. After calibrating the model to replicate the macroeconomic and fiscal structure of Europe at the beginning of the 1980s—that is, the period before the introduction of major liberalization reforms—the model is used to evaluate the consequences of capital market liberalization experienced by the European countries in the last two decades. The changes in tax structure predicted by the model are roughly consistent with the observed changes and they have led to a welfare gain of about 1 percent.

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[3]The quantitative nature of the exercise is similar to Klein, Quadrini, & Rios-Rull (1999) who study differences in taxation structure between the U.S. and Europe. Their analysis, however, is limited to steady state equilibria while the current paper studies the transition dynamics induced by capital market liberalization.

Mendoza & Tesar (2003) also evaluate the welfare consequences of tax competition among European countries. Their analysis is different from the current paper in several dimensions. They also consider consumption taxes and the government budget does not have to balance in every period. However, they do not consider the issue of time consistency given that the policy game is played only once by the two governments.

The organization of the paper is as follows. Section 2 provides some further evidence about the dynamics of the taxation structure in Europe. Section 3 describes the economic model and Section 4 characterizes the optimization problems of firms, households and governments, and defines the policy equilibrium. Section 5 describes the calibration of the model and Section 6 studies the transition dynamics induced by the liberalization of capital. Section 7 conducts a sensitivity analysis and Section 8 concludes.

2 More evidence on the changes in the European tax structure.

Figure 1 has shown the pattern of the implicit tax rates on capital and labor among European countries in the 1980s and the 1990s as reported by Eurostat (2000). Similar figures for the largest European countries are reported in Mendoza & Tesar (2003) who update earlier numbers by Mendoza, Razin, & Tesar (1994). According to this paper, the effective capital income tax has been declining since the beginning of the 1980s in France, Germany and the United Kingdom. For Italy, the declining trend seems to start in the middle of the 1990s. The effective tax rate on labor income, instead, has increased in France, Germany and Italy. The only exception is the United Kingdom where labor taxes seems to remain low or they even decline. Overall, these figures show that the average taxation of capital has declined and the taxation of labor has increased in the European area during the last 2 decades, that is, during the period in which these countries have introduced reforms to liberalize their capital markets.

The decline in capital taxes is especially important for the income generated by foreign affiliates operating in Europe. Desai, Foley, & Hines (2002) compute effective average income tax rates for foreign affiliates of U.S. multinationals operating in European countries for the years 1982, 1989, 1994, and 1997. These tax rates are reported in Table 1.

Table 1: Effective income tax rates for affiliates of U.S. multinationals operating in European countries.

	1982	**1989**	**1994**	**1997**
Belgium	29.9	24.2	19.3	27.4
France	44.6	35.8	22.8	29.0
Germany	42.2	38.1	31.8	33.7
Ireland	3.8	2.3	9.5	9.1
Italy	36.5	40.3	33.4	41.0
Netherlands	40.2	21.2	24.1	17.2
Spain	24.6	23.6	22.6	24.6
Sweden	44.1	34.5	19.3	20.6
United Kingdom	57.5	29.0	27.8	24.9
Switzerland	15.9	12.9	6.8	8.8
EU averages (weighted by GDP)	42.0	33.3	27.6	30.2

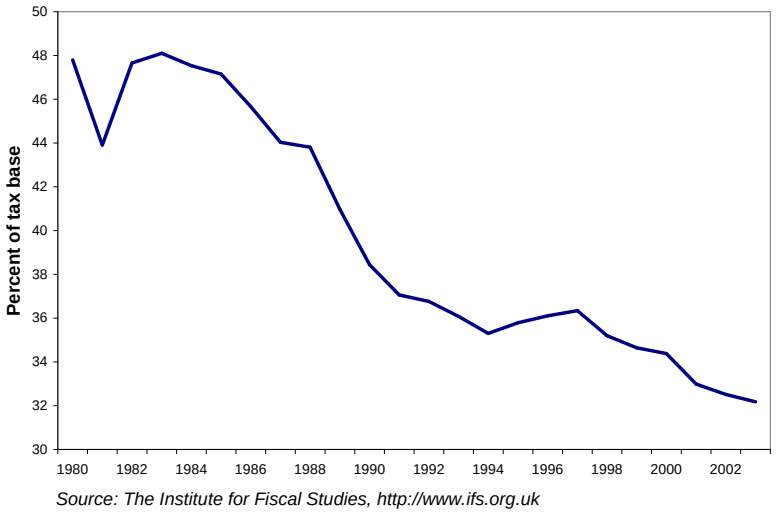
Source: Desai et al. (2002)

In several countries, the effective tax rates paid by foreign affiliates of U.S. multinationals in the 1990s are about half the tax rates paid at the beginning of the 1980s. This is the case for France, Netherlands, Sweden, Switzerland and the United Kingdom. In Belgium and Germany the fall is not as big but still large. There are only few countries in which the tax rates have not declined. These includes Ireland, Italy and Spain. For Ireland and Spain, however, the tax rates were already quite low at the beginning of the 1980s and they remained low in the 1990s. The only relevant exception is Italy. The (weighted) average tax rate on foreign affiliates for the EU countries has declined from 42 percent to about 28 percent in 1994. In 1997 the average tax rate was about 30 percent.

Figure 2 shows another indicator of the declining tax pressure on business income in the European area. The figure plots the average statutory corporate tax rates during the

period 1980 to 2003. The corporate tax rate has declined steadily during the last two decades from an average of 48 percent at the beginning of the 1980s to an average of 32 percent in 2003. The declining pattern is observed in almost all countries as shown in Table 6 in the appendix. Although the statutory tax rate does not completely capture the whole tax pressure on corporate profits, it is a good proxy for the marginal tax rate, which is important for economic decisions.

Figure 2: Statutory corporate tax rates. Average of European Union countries.



Source: The Institute for Fiscal Studies, http://www.ifs.org.uk

3 The economic model

The model is a two-country growth model extended to include a government sector. Countries are symmetric in technology and preferences and are indexed by $i \in \{1, 2\}$.

Households: In each country there is a continuum of households of total measure μ_i. The household's objective is $\sum_t \beta^t u(c_{it}, h_{it})$, where c_{it} and h_{it} are consumption and hours worked at time t. Households cannot change their country of residence, which implies that labor is immobile. They own assets representative of the ownership of domestic

firms. These assets are denoted by a_{it}.

Firms: In both countries there is a continuum of firms owned by domestic residents. Firms operate the constant return to scale production function $F(k_{it}, h_{it})$, where k_{it} is the input of capital and h_{it} is the input of labor. If there is international mobility of capital, firms can operate and produce in both countries. Given k_t the total capital owned by a firm, it allocates k_{1t} units in country 1 and k_{2t} in country 2, where $k_{1t} + k_{2t} \leq k_t$. After hiring labor h_{1t} and h_{2t}, the output produced by the firm is $F(k_{1t}, h_{1t})$ in country 1 and $F(k_{2t}, h_{2t})$ in country 2.[4]

Let A_i be the per-household capital owned by firms in country i and K_i the per-household capital used in country i.[5] The variable A_i represents the country's wealth. Without international mobility of capital $A_i = K_i$. With mobility, however, the country's wealth may differ from the capital used in that country. Only the worldwide constraint $\sum_{i=1,2} \mu_i A_i = \sum_{i=1,2} \mu_i K_i$ must be satisfied.

Government: The governments of the two countries finance public expenditures by taxing firms' profits at rate τ_{it}^P, capital income at rate τ_{it}^A and labor income at rate τ_{it}^L. In strict sense firms do not make profits. What I refer to firms' profits is the non-labor income generated by the firm (net production minus the cost of labor). Capital income is then the payment that the investor receives from the firm, that is, firm's profits minus the taxes on profits.

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[4]The equilibrium allocation would not change if I make the alternative assumption that households own directly the capital that they rent to both domestic and foreign firms.

[5]In what follows I will use capital letters to denote aggregate per-capita variables and small letters to denote individual variables and prices.

Public expenditures are composed of government purchases, G_i, and transfers, T_i. The flows of public expenditures are exogenous in the model and government purchases do not enter directly the households' utility. The government budget must balance in every period.

The government chooses the current tax rates at the beginning of every period and there is no form of commitment. The lack of commitment implies that, in absence of capital mobility, governments have an incentive to use only profits and capital income taxes to finance public expenditures. To prevent this, I assume that the profit and capital income tax rates are subject to some upper bounds, that is, $\tau_{it}^P \leq \bar{\tau}^P$, $\tau_{it}^A \leq \bar{\tau}^A$. There are different ways to justify these upper bounds. Tax evasion and/or tax elusion are some possibilities. For example, we could assume that firms and citizens are able to use legal and illegal strategies to reduce the tax burden on profits and capital incomes. Because the use of these strategies are more likely when the tax rates are high, the tax revenue raised by taxing profits and capital incomes may actually decrease once the tax rates have reached certain levels. For simplicity, the paper does not model explicitly these strategies but incorporates this idea by imposing the exogenous bounds $\bar{\tau}^P$ and $\bar{\tau}^A$.

4 Policy equilibrium

In this section I define the equilibrium of the policy game that the governments of the two countries play with each other when there is international mobility of capital. In order to derive the objective function of the two governments, I need first to solve for the competitive equilibrium for given policy rules. Therefore, in the next subsection, I describe the optimization problem solved by firms and households when current and future tax rates are determined by some policy rule $\Psi(\mathbf{s}) = \{\Psi_i^P(\mathbf{s}), \Psi_i^A(\mathbf{s}), \Psi_i^L(\mathbf{s})\}_{i=1,2}$, where $\mathbf{s}$ denotes the set of aggregate states as defined below. The policy rule depends

only on **s** because the analysis is restricted to Markov strategies. Once I have solved for the agents' problem for given policy rules, subsection 4.2 will derive the policy objectives of the two governments and will define the time-consistent policy rules.

4.1 Agents' problem and equilibrium for a given policy rule

Firm's problem: Denote by k the capital owned by the firm at the beginning of the period. The firm allocates these resources between the two countries and hire local labor to maximize profits. The optimization problem is:

$$\max_{k_1,k_2,h_1,h_2} \quad \sum_{i=1,2} \Big[F(k_i,h_i) - \delta k_i - w_i h_i\Big](1-\tau_i^P) \qquad (1)$$
$$\textbf{s.t.} \quad \sum_{i=1,2} k_i = k$$

where w_i is the wage rate in country i. The wages are determined by the aggregate equilibrium condition in the labor markets of the two countries and they are taken as given by the firm. The solution is characterized by the following first order conditions:

$$\Big[F_k(k_1,h_1) - \delta\Big](1-\tau_1^P) = \Big[F_k(k_2,h_2) - \delta\Big](1-\tau_2^P) \qquad (2)$$
$$F_h(k_i,h_i) = w_i\,, \qquad i=1,2 \qquad (3)$$

The firm chooses the allocation of capital and employment so that the marginal net profits are equalized and the marginal productivities of labor equal the wage rates.

Because the return from capital, net of the profit tax, is equalized across countries, in equilibrium households in both countries receive the same return from their investment. This return is denoted by r.

Household's problem: The household's problem is specified recursively. The aggregate states are the cross-country distribution of assets, $\mathbf{s} \equiv (A_1, A_2)$, and the individual state is the asset holding a. Given a policy rule $\Psi(\mathbf{s})$ that returns the current tax rates as a function of the aggregate states, and given a law of motion for the aggregate states $\Phi(\mathbf{s}; \Psi)$, the agent's problem can be written as:

$$
\begin{aligned}
V_i(\mathbf{s}, a; \Psi) &= \max_{c,h,a'} \left\{ u(c,h) + \beta V_i\left(\mathbf{s}', a'; \Psi\right) \right\} && (4)\\
&\quad \textbf{s.t.} \\
c &= (1-\tau_i^L) w_i h + \Big[1 + r(1-\tau_i^A)\Big] a + T_i - a' && (5)\\
r &= r(\mathbf{s}; \Psi) && (6)\\
w_i &= w_i(\mathbf{s}; \Psi) && (7)\\
\tau_i^A &= \Psi_i^A(\mathbf{s}) && (8)\\
\tau_i^L &= \Psi_i^L(\mathbf{s}) && (9)\\
\mathbf{s}' &= \Phi(\mathbf{s}; \Psi) && (10)
\end{aligned}
$$

Equation (5) defines the budget constraint, where w_i is the wage rate and r is the assets' return as defined below. To make explicit that this problem is conditional on the particular policy rule Ψ, I have included this function as an argument in the agent's value function and in the law of motion for the aggregate states. The solution is given by the current hours worked, $h = g_{i,h}(\mathbf{s}, a; \Psi)$, and next period assets $a' = g_{i,a}(\mathbf{s}, a; \Psi)$. They satisfy the first order conditions:

$$
\begin{aligned}
-u_h(c,h) &= w_i(1-\tau_i^L)\, u_c(c,h) && (11)\\
u_c(c,h) &= \beta\Big[1 + r'(1-\tau_i^{A'})\Big]\, u_c(c',h') && (12)
\end{aligned}
$$

Equilibrium for a given Ψ: A *Recursive competitive equilibrium* for a given policy rule Ψ is given by: (i) aggregate functions $r(\mathbf{s};\Psi)$, $w_i(\mathbf{s};\Psi)$, $K_i(\mathbf{s};\Psi)$, $H_i(\mathbf{s};\Psi)$ and $\Phi_i(\mathbf{s};\Psi)$ for households' asset return, wage rates, allocation of capital, input of labor and law of motion for the aggregate states; (ii) household values, $V_i(\mathbf{s},a;\Psi)$, and decision rules, $g_{i,h}(\mathbf{s},a;\Psi)$ and $g_{i,a}(\mathbf{s},a;\Psi)$. Such that: (i) the allocation of capital between the two countries K_i and the inputs of labor H_i satisfy (2) and (3); (ii) the decision rules $g_{i,h}(\mathbf{s},a;\Psi)$ and $g_{i,a}(\mathbf{s},a;\Psi)$ solve the households' problem and $V_i(\mathbf{s},a;\Psi)$ is the associated value function; (iii) Households are representative, that is, $g_{i,a}(\mathbf{s},A_i;\Psi)=\Phi_i(\mathbf{s};\Psi)$ and $g_{i,h}(\mathbf{s},A_i;\Psi)=H_i(\mathbf{s};\Psi)$; (iv) both governments balance their budget every period, that is, $[F(K_i,H_i)-\delta K_i-w_iH_i]\tau_i^P+rA_i\tau_i^A+w_iH_i\tau_i^L=G_i+T_i$; (v) all markets clear.

4.2 The determination of policies

In choosing the current tax rates (current policies), the policy maker of each country takes as given the rule that determines future policies—the function Ψ—and the policy variables of the other country, $\{\tau_{i^c}^P,\tau_{i^c}^A,\tau_{i^c}^L\}$. The superscript c in the country index denotes its complement value.

I first define the equilibrium when the current policies are exogenously given and future policies are determined by Ψ. Let's use π as a compact notation for the current policies, that is, $\pi=\{\pi_1,\pi_2\}=\{\tau_1^P,\tau_1^A,\tau_1^L,\tau_2^P,\tau_2^A,\tau_2^L\}$. Consider the problem solved by an individual household when the current tax rates are π and future tax rates will be determined by some policy rule Ψ. The household's problem is:

$$\begin{aligned}\hat{V}_i(\mathbf{s},a,\pi;\Psi) &= \max_{c,h,a'}\left\{u(c,h)+\beta V_i\left(\mathbf{s}',a';\Psi\right)\right\} &(13)\\ &\quad \textbf{s.t.}\\ c &= (1-\tau_i^L)w_ih+\left[1+r(1-\tau_i^A)\right]a_i+T_i-a_i' &(14)\end{aligned}$$

$$r = \hat{r}(\mathbf{s}, \pi; \Psi) \tag{15}$$

$$w_i = \hat{w}_i(\mathbf{s}, \pi; \Psi) \tag{16}$$

$$\mathbf{s}' = \hat{\Phi}(\mathbf{s}, \pi; \Psi) \tag{17}$$

Notice that the next period value function is the value function for given Ψ as defined in the previous section. For the current period, instead, the value function is indexed by the current policies π. All functions that are affected by π are denoted with hats.

The solution is given by the functions $h = \hat{g}_{i,h}(\mathbf{s}, a, \pi; \Psi)$ for the supply of labor and $a' = \hat{g}_{i,a}(\mathbf{s}, a, \pi; \Psi)$ for the next period assets. The definition of the equilibrium for given current policies π is analogous to the definition provided in the previous section.

The function $\hat{V}_i(\mathbf{s}, A_i, \pi; \Psi)$, when evaluated at the per-capita asset holding A_i, represents the objective of the policy maker of country i. We then have the following definition:

Definition 4.1 (Nash one-step equilibrium) *Given the policy rule Ψ, a Nash one-step equilibrium of the policy game is a function $\pi(\mathbf{s}; \Psi) = (\pi_1(\mathbf{s}; \Psi), \pi_2(\mathbf{s}; \Psi))$ such that $\pi_i(\mathbf{s}; \Psi)$ maximizes $\hat{V}_i(\mathbf{s}, A_i, \pi(\mathbf{s}; \Psi); \Psi)$ taking as given $\pi_{i^c}(\mathbf{s}; \Psi)$.*

The function $\pi(\mathbf{s}; \Psi)$ is the equilibrium "current policy rule" when the two policy makers expect that future policies will be determined by the policy rule $\Psi(\mathbf{s})$. We now have all the elements to define the equilibrium time-consistent policies.

Definition 4.2 (Time-consistency) *The policy rule $\Psi(\mathbf{s})$ is time-consistent if $\Psi(\mathbf{s}) = \pi(\mathbf{s}; \Psi)$.*

In other words, the policy rule Ψ is time consistent if the solution to the current policy game replicates this rule.

4.3 Some basic properties of the equilibrium

As is well known in the optimal taxation literature in closed economies, the optimal policy with commitment taxes capital heavily in the current period and then it gradually reduces the taxation of capital in future periods. In the long-run, capital taxes should be approximately zero. Without commitment, the time-consistent policy is closer to the policy implemented in the first period of the optimal plan. The result is that capital will be heavily taxed not only in the current period but also in the long run. A similar result applies to the model studied in this paper if there is not international mobility of capital. This is summarized in the following property:

Property 1 *In autarky, the optimal time-consistent policy uses the profit tax and the capital income tax first, up to the limits.*

This property is obvious once we consider that in a closed economy the profit tax and the capital income tax are not distortionary in the current period. Capital has already been accumulated and it cannot be reallocated abroad. On the other hand, the labor tax distorts the supply of labor. Therefore, the benevolent government prefers to tax capital rather than labor. If the taxation of capital is not sufficient to finance government spending (given that the feasible capital tax rates are bounded), the government will use the labor tax. In this case the equilibrium can be easily calculated after setting $\tau_t^A = \bar{\tau}^A$ and $\tau_t^P = \bar{\tau}^P$. The use of the first order conditions (11) and (12) and the government budget constraint (which determines residually the labor tax rate) will provide the sufficient conditions to solve the model.

The international liberalization of capital will change the properties of the equilibrium policies as follows:

Property 2 *With capital mobility, the time-consistent policy uses the capital income tax first, up to the limit, but the profit tax could be smaller than the limit.*

Even with capital mobility, the personal capital income tax does not have distortionary consequences in the current period because it is based on the residence principle. On the other hand, the profit tax affects the international allocation of capital between the two countries. By increasing the profit tax, part of the capital will be reallocated to the other country. From the government point of view, this is clearly undesirable because it reduces the productivity of local workers. Therefore, the government will try to raise as much revenue as possible by taxing the capital incomes received by the households. Once the capital income tax rate has reached the maximum, the government faces a trade-off between the choice of profit taxes and labor income taxes. Lowering the taxation of profits attracts foreign capital but it requires higher taxation of labor which is distortionary. If government spending is sufficiently large, the equilibrium will be characterized by some taxation of profits and some taxation of labor income. The whole taxation of capital—profits plus capital income taxes—is in general smaller with international mobility of capital.

The computation of the equilibrium is now more complex. Although the capital income tax rate can be set to $\tau_t^A = \bar{\tau}^A$ and the labor tax rate is determined residually through the government budget constraint, the solution for the profit tax rates chosen by the two governments may be interior. The numerical procedure solves the model globally by approximating the policy rule Ψ. The detailed description of this procedure is provided in the appendix.

Before turning to the quantitative analysis, I shall point out another important property of the model. Given the initial states (A_1, A_2), the equilibrium will converge to a steady state. However, in the regime with mobility of capital, the final steady state de-

pends on the initial conditions. In the numerical exercises conducted in the next sections the initial conditions are always given by the steady state assets before the liberalization of capital. This eliminates any ambiguity because in autarky the steady state equilibrium is always unique.

5 Calibration: the pre-liberalization stage

The model is parameterized to replicate some calibration targets for the European countries at the beginning of the 1980s. Because at the beginning of the 1980s there were substantial capital controls, the strategic interaction among the European countries during this period is approximated by a regime of autarky. Starting from this baseline economy, I will study how the subsequent liberalization of capital has impacted on the taxation structure and on other macroeconomic variables.

I begin with the symmetric model in which $\mu_1 = \mu_2 = 1$ (same population). Obviously, there are many sources of heterogeneity across the European countries which is impossible to model explicitly here. However, the exercise is based on the view that the symmetric model is able to capture some of the important strategic features of the international policy competition. Later, I will extend the analysis to the case in which countries are heterogenous in the size of the population and productivity.

The model period is one year. The utility of the representative household takes the form $u(c,h) = \log(c) - \alpha h^{\frac{1+\epsilon}{\epsilon}}$ where ϵ is the elasticity of labor supply. This specification of preferences is widely used in macroeconomic studies. Following these studies I set $\epsilon = 1$. A sensitivity analysis with respect to ϵ will be also conducted. The parameter α is such that in the steady state with autarky agents spend one third of their time working, that is, $h = 1/3$. Different values of α do not affect the results.

The production function is Cobb-Douglas, that is, $F(K,H) = K^{\theta}H^{1-\theta}$. The capital

income share θ is set to 0.36 and the depreciation rate to $\delta = 0.08$. The discount factor β is then chosen so that the capital-output ratio in autarky is 2.8, which is the average ratio in the business sector for the European countries at the beginning of the 1980s. The required value is $\beta = 0.98$. Given the presence of taxes as specified below, this implies a pre-tax interest rate of 4.7 percent, which is in line with the usual calibration of macro models without taxes.

According to Eurostat (2000), the tax revenues raised by European countries with the taxation of capital and labor at the beginning of the 1980s were about 30 percent of GDP.[6] Because in the model the government budget must balance, the total expenditures are also 30 percent of GDP. The composition of public expenditures is 55 percent government purchases and 45 percent transfers, which is consistent with the European composition according to OECD data.

An important parameter is the upper bound on the profit tax rate $\bar{\tau}^P$. I use the effective tax rate paid by foreign affiliates at the beginning of the 1980s to calibrate this parameter. As reported in Table 1, the average effective tax rate paid by foreign affiliates of U.S. multinationals operating in the European Union was 42 percent in 1982. Because in autarky the profit tax rate is set to the upper bound, I choose $\bar{\tau}^P = 0.42$. The assumption here is that foreign affiliates of European multinationals operating in Europe were receiving the same tax treatment of U.S. affiliates. After fixing $\bar{\tau}^P$, the upper bound on the personal capital income tax rate is chosen such that the implicit tax rate on labor in the steady state with autarky is equal to the implicit tax rate for the EU countries at the beginning of the 1980s. As shown in Figure 1, this was about 35 percent. The

[6]With the addition of consumption taxes the tax revenues was about 40 percent. Because consumption taxes are not explicitly modelled, the calibration will consider only the revenues from the taxation of capital and labor.

required value of $\bar{\tau}^A$ is 0.25. The full set of parameter values are reported in Table 2.

Table 2: Parameter values.

Discount rate	β	0.98
Disutility parameter	α	3.00
Labor elasticity	ϵ	1.00
Capital income share	θ	0.36
Depreciation rate	δ	0.08
Maximum tax rate on profits	$\bar{\tau}^P$	0.42
Maximum personal tax rate on capital income	$\bar{\tau}^A$	0.25
Government purchases	G/GDP	0.165
Government transfers	T/GDP	0.135

The steady state values of several macroeconomic and fiscal variables are reported in Table 3. Few points should be emphasized. The first is that the implicit rate for the whole taxation of capital is larger than the number reported in Figure 1. This is not inconsistent with the model once we recognize that in the real economy there is a large portion of economic activities that are exempted from the taxation of profits. The non-corporate sector, for example, is exempted from corporate taxes. If the paper had explicitly modelled the non-corporate sector, the whole implicit tax rate on capital would have been similar to the data.

The second point to emphasize is that the composition of revenues from capital and labor is similar to the data. In 1980, Eurostat (2000) reports that 69 percent of revenues (excluding consumption) were raised by taxing employed labor, 8 percent by taxing self-employed income and 23 percent by taxing capital (excluding the one generated by self-employed). If we attribute 2/3 of the taxation of self-employed income to labor and 1/3 to capital, the whole taxation of labor was close to 75 percent of revenues as in the model.

Table 3: Fiscal and macroeconomic variables in the steady state with autarky.

Implicit tax rates	
Labor income tax, τ^L	35.0
Profit tax, τ^P	42.0
Personal capital income tax, τ^A	25.0
Whole taxation of capital	56.5
Percent of revenues from tax source	
Labor income taxes	75.0
Profit taxes	18.6
Personal capital income taxes	6.4
Macroeconomic variables	
Output	0.607
Private consumption	0.369
Private investment	0.138
Government purchases	0.100
Government transfers	0.082
Working hours	0.333
Capital stock	1.720

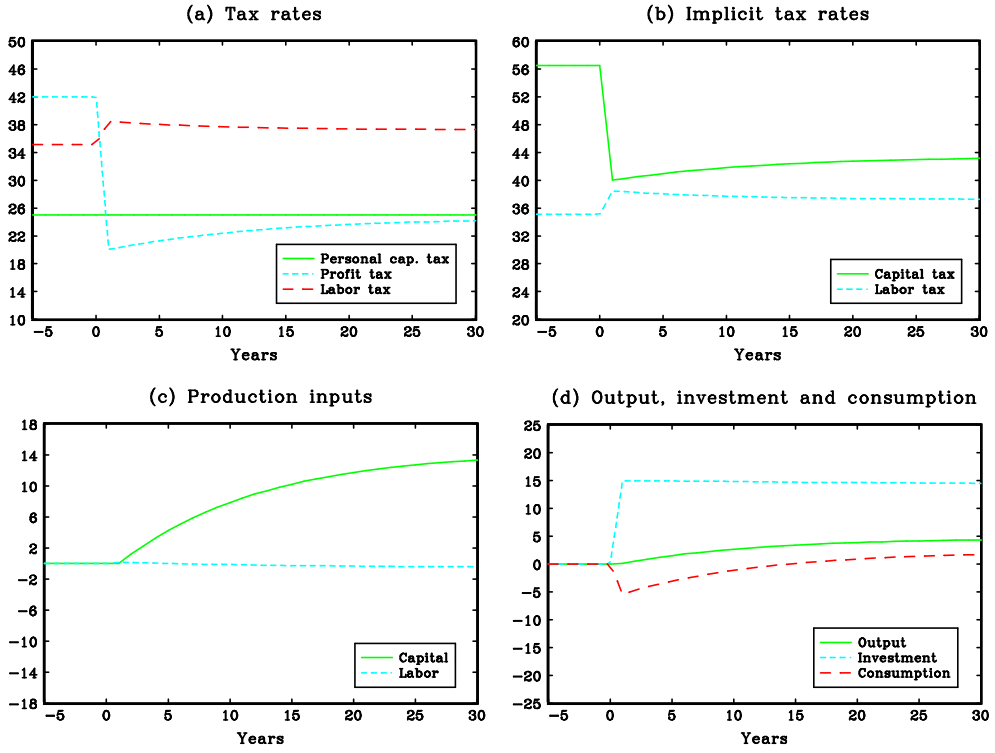
6 The impact of capital market liberalization.

Starting from the steady state with autarky, this section studies the transition dynamics of the two economies after the liberalization of capital. The consequences of capital market liberalization are evaluated under two alternative assumptions. In the first simulation it is assumed that the value and composition of government spending remain constant after liberalization. In the second simulation, instead, it is assumed that the value and composition of government spending changes (exogenously) during the period of the transition as observed for the EU countries. While the first simulation allows us to evaluate the consequences of capital market liberalization in general, the second is specific for the integration experience of the European countries.

6.1 Liberalization with unchanged public spending

Figure 3 plots the transition dynamics of several variables after the liberalization of capital, keeping constant the absolute value and composition of public spending. The transition dynamics is based on the assumption that the liberalization reform was not anticipated (otherwise the economy would not start from the steady state with autarky).

Figure 3: Transition dynamics after capital liberalization.



The first panel plots the dynamics of the three tax rates. The personal capital income tax rate remains constant to the upper bound $\bar{\tau}^A = 0.25$. As observed in Section 4.3, the liberalization of capital does not change the government incentive to tax the capital income based on the residence principle. The profit tax rate, instead, falls drastically after liberalization. To compensate for the fall in revenues following the reduction in the taxation of profits, the two governments have to raise the taxes on labor. After the initial

impact, the profit tax rate gradually increases and the labor tax rate gradually decreases. However, these patterns do not compensate for the initial changes. Therefore, the two economies will have lower profit taxes and higher labor taxes also in the long-run. The implicit tax rate on capital (including both profit and personal capital incomes taxes) falls by 13 percentage points. The fall in the capital tax is compensated by a 2 percent increase in the labor tax rate (see panel *b*).

The lower taxation of capital increases the incentive to save which increases the stock of capital as shown in panel *c*. This panel also shows the dynamics of labor, which is affected only marginally by the tax change. Panel *d* plots the dynamics of output, investment and private consumption. Because capital is fixed in the first period, the increase in investment must be associated with an initial fall in consumption. In the long-run, however, output increases permanently due to the increase in the stock of capital and this allows consumption to increase above the pre-liberalization level.

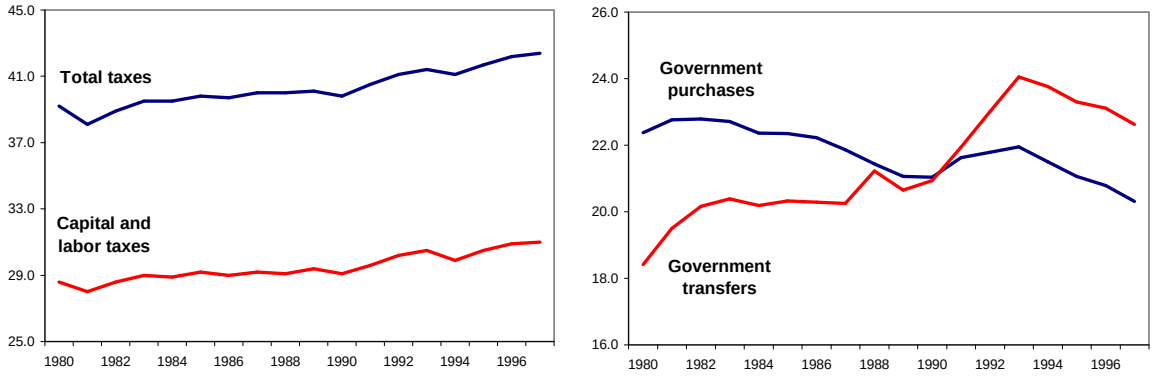
The welfare gains associated with the transition to the regime with mobility of capital are about 1 percent of consumption. These gains are computed as the percent increase in autarky consumption necessary to make households indifferent between remaining in autarky (but with the higher consumption) and opening the economy to the international capital markets. The gains derive from the fact that capital liberalization introduces an incentive for the policy makers of the two countries to reduce capital taxes and it corrects for the over-taxation of capital induced by the lack of policy commitment.

6.2 Liberalization with changed public spending

The transition dynamics shown in the previous section is based on the assumption that the two countries do not change the absolute value of public spending after liberalization. This implies that the size of government spending, as a percentage of aggregate output,

declines over time. During the past two decades, however, European countries have not experienced a decline in the relative size of the public sector (measured in both public spending or overall taxation). As shown by the first panel of Figure 4, total taxes, as a percentage of GDP, has increased by about 3 percentage points. If we exclude consumption taxes, the increase has been about 2 percent. Moreover, this increase in taxation financed mainly government transfers. The second panel of Figure 4 shows that government purchases (consumption plus investment) either remained stable or declined as a percentage of GDP, while government transfers increased.[7]

Figure 4: Taxes and government spending in Europe.



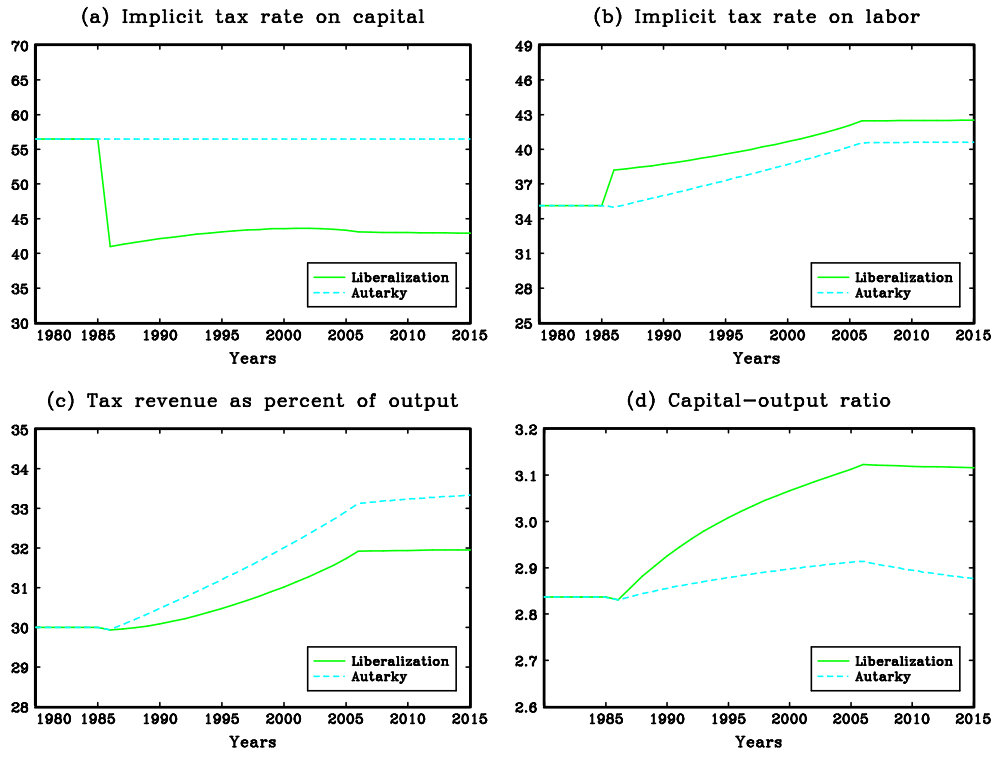
Source: Eurostat (2000) *Source: OECD statistical compendium*

To capture the pattern in the size of the European public sector, I assume that government purchases and transfers increase gradually after liberalization so that in the new steady state the size of the government, relative to output, is 2 percent higher. Of this, 15 percent are government purchases and 17 percent government transfers. The increase in the absolute value of government spending is assumed to take place in the 20 years following capital liberalization.

[7]Government transfers include social security benefits, government subsidies and other transfers as reported in the OECD Statistical Compendium.

The transition dynamics with and without capital liberalization is plotted in Figure 5. As a reference date, I have chosen the year 1986 as the starting point for the liberalization process. This is justified by the fact that concrete liberalization plans started to emerge in the second half of the 1980s.[8]

Figure 5: Transition dynamics after capital liberalization with increase in government spending.



Panels *a* and *b* of Figure 5 plot the pattern of the implicit tax rates on capital and labor. The implicit tax rate on capital falls drastically after liberalization and then stabilizes to a lower level. The tax rate on labor, instead, gradually increases in both economies with

[8]Examples are the Single European Act in 1987 that approved some legislation promoting the liberalization of capital and the Delors Report in 1989 setting the stages for the introduction of the single currency.

and without capital mobility. However, the increase in the labor tax rate is higher in the economy with capital mobility. This is because labor taxes must compensate for the fall in revenues following the decrease in capital taxes.

The pattern and levels of the labor tax rate is close to the pattern of the implicit tax rate on labor shown in Figure 1. The pattern of the implicit tax rate on capital, however, is more gradual in the data. However, this can be easily accounted if we assume that capital liberalization arose gradually, let's say, during a period of 10 years rather than in only one period. Alternatively, it is possible to assume that the liberalization of capital occurred in one year, but there was a learning period for firms to operate in foreign countries. The fall in capital taxes is due to the decrease in the tax rate on profits, which drops by 18 percentage points. This is not very different from the drop in the taxation of foreign affiliates as reported in Table 1 and from the fall in statutory corporate tax rates shown in Figure 2. For example, in 1994, the average tax rate for U.S. foreign affiliates was 14.4 percent lower than in 1982 and the average corporate tax rate has decreased by 16 percentage points since the early 1980s. The welfare gains from capital liberalization are about 1 percent of consumption.

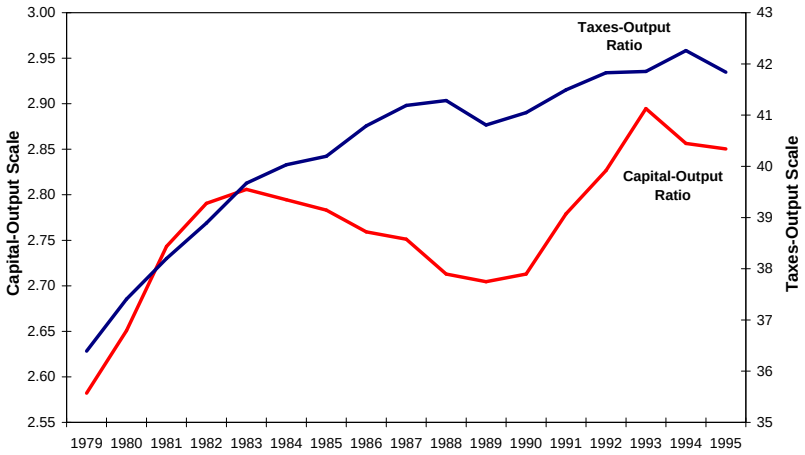
Panel *c* plots the total tax revenues as a percentage of output. Here we observe that the relative size of the government would have been larger without the liberalization of capital. This is because, in absence of capital mobility, output would have been lower.

Finally, panel (f) plots the capital-output ratio, which increases after the liberalization of capital. This is not inconsistent with the European data as shown in Figure 6. This figure plots the capital-output ratio in the business sector and the total tax revenues as a percentage of GDP, for 14 countries that are currently members of the European Union.[9] Despite the increase in tax pressure, the capital-output ratio has increased in Europe.

[9]Total taxation also includes consumption taxes that were excluded in the calibration of the model.

This is not surprising if we take into account that the increase in taxation did not lead to higher capital taxes as shown in figure 1. I should also point out, however, that there are alternative explanations for the increase in the capital-output ratio. Caballero & Hammour (1997), for example, argue that a change in industrial relations in the early 70's increased the cost of labor and firms slowly adopted labor-saving technologies with a subsequent raise in the capital-output ratio.

Figure 6: Capital-output ratio in the European business sector.



Source: OECD statistical compendium

7 Country heterogeneity and sensitivity analysis

The assumption that countries are homogeneous is a modelling abstraction that captures the average welfare consequences of capital liberalization for the whole area. With heterogeneity, however, these gains are not equally distributed among the liberalizing countries. In this section I extend the model by allowing heterogeneity in population size and productivity.

Table 4 reports the initial and limiting steady state variables when the population of country 2 is 50 percent larger than the population of country 1 and when the total

factor productivity of country 2 is 20 percent higher than in country 1. The production function is now specified as $z_i F(k_i, h_i)$ with $z_1 = 1$ and $z_2 = 1.2$. In the pre-liberalization steady state, the two countries have the same tax rates even if they are heterogeneous in population and total factor productivity. After liberalization, however, they choose different profit (and labor) taxes. The equilibrium under capital mobility is computed assuming that the size and composition of the government expenditures do not change.

Table 4: Fiscal and macroeconomic variables in the limiting equilibrium after liberalization when countries are heterogeneous in the size of the population and total factor productivity.

	Population of country 2 is 50 percent larger		*TFP of country 2 is 20 percent higher*	
	Country 1	Country 2	Country 1	Country 2
Implicit tax rates				
Labor income tax, τ^L	37.7	36.8	37.5	36.9
Profit tax, τ^P	20.6	28.4	21.8	27.2
Personal capital income tax, τ^A	25.0	25.0	25.0	25.0
Whole taxation of capital	39.9	46.7	40.9	45.7
Macroeconomic variables (*Percent change from autarky*)				
Output	5.5	3.6	5.2	3.9
Private consumption	2.3	2.0	2.3	2.0
Working hours	-0.4	-0.5	-0.5	-0.5
Capital stock	17.0	11.2	16.2	12.1
Domestic wealth	13.5	13.5	13.8	13.9
Welfare gains from liberalization	1.11	0.84	1.08	0.89

Table 4 shows that the country with the smaller population and with the lower productivity, *i.e.*, country 1, reduces the taxation of capital more than country 2. As a consequence of the larger reduction in capital taxation, country 1 experiences higher welfare gains.

To understand this result, consider first the case of countries with different population sizes. The smaller country chooses a greater reduction in the taxation of capital because

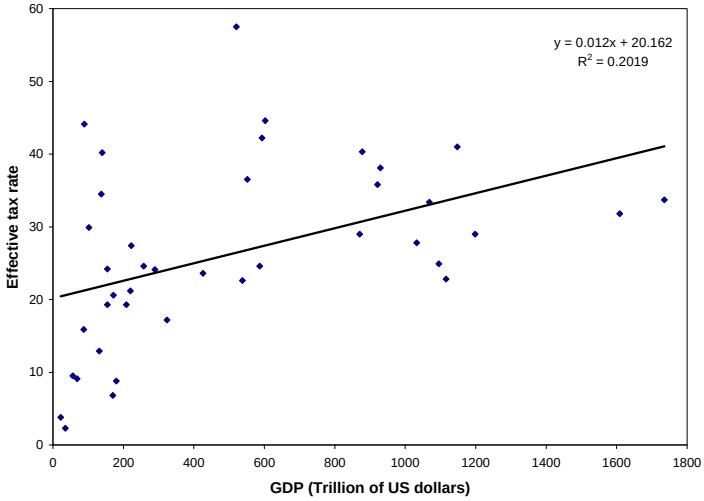
this country is more vulnerable to capital flights. Suppose that country 1 is 10 times smaller than country 2. If 10 percent of country 1's capital gets reallocated to country 2, the capital used by the second country increases only by 1 percent. This implies a small drop in the productivity of capital in country 2. Now consider the opposite case in which 10 percent of the capital of country 2 gets reallocated to country 1. This implies a 100 percent increase in the capital used in country 1 with a large fall in its marginal productivity. The rapid fall in the marginal productivity of capital in country 1 implies that a change in the taxation of profits will trigger only a (relatively) small outflow of capital from country 2. The same considerations apply to the case of countries heterogeneous in productivity. The less productive country is basically smaller in economic terms. Therefore, it is more vulnerable to capital flights as countries with smaller populations.

Table 4 shows another interesting result. After the liberalization of capital, country 1 imports capital from country 2, that is, $A_1 < K_1$ and $A_2 > K_2$. This is shown in the table by the fact that the capital stock used in country 1 increases more than its wealth.

The relation between the economic size of the country and the taxation of capital is supported by the data for the European countries. Figure 7 relates the GDP of 10 European countries with their taxation of foreign affiliates of U.S. multinationals. The plotted points are for the countries and years reported in Table 1. This figure shows that there is a positive correlation between the economic size of these countries and the taxation of capital income generated by the highly mobile capital of foreign multinationals. The correlation coefficient is 0.45.

This section concludes by conducting a sensitivity analysis with respect to the elasticity of labor ϵ and the upper bound on the taxation of profits $\bar{\tau}^P$. The second column of Table 5 reports the simulation results when the elasticity of labor is $\epsilon = 0.5$ (in the baseline model the elasticity is 1.0). In changing ϵ I also change the parameter α so that the steady

Figure 7: Correlation between the effective tax rates for U.S. foreign affiliates operating in Europe and the GDP of the hosting country.



Source: Desai et al. (2002) and OECD statistical compendium

state labor supply does not change. The table shows that when the supply of labor is more rigid, the reduction in the profit tax rate is bigger and the welfare gains larger.

To understand this results, we should recognize that a reduction in profit taxes has two effects in attracting foreign capital (or retaining domestic capital). On the one hand it has a positive effect because it increases the after tax return on capital. On the other, the reduction of capital taxes must be compensated by an increase in the taxation of labor. This will distort the supply of labor which in turn affects negatively the pre-tax return on capital. When labor is rigid, the negative indirect effect is less important and the two countries choose a lower taxation of capital. This, in turn, increases the welfare gains from the liberalization of capital.

An alternative interpretation of the elasticity of labor is that it proxies for the international mobility of labor. Lower is this mobility, and less distortionary is the taxation of labor. From this we can infer that, as the mobility of labor increases within European countries, we might observe in the future a reversion of the previous trend in tax structure,

Table 5: Fiscal and macroeconomic variables in the limiting equilibrium after liberalization for alternative values of the elasticity of labor ϵ and the upper bound on the profit tax rate $\bar{\tau}^P$.

	Baseline	$\epsilon = 0.5$	$\bar{\tau}^P = 0.36$
Implicit tax rates			
Labor income tax, τ^L	37.2	37.4	36.9
Profit tax, τ^P	24.5	22.5	20.3
Personal capital income tax, τ^A	25.0	25.0	32.0
Whole taxation of capital	43.3	41.9	45.8
Macroeconomic variables			
(*Percent change from autarky*)			
Output	4.6	5.1	3.8
Private consumption	2.2	2.6	1.9
Working hours	-0.5	-0.3	-0.4
Capital stock	14.2	15.6	11.8
Welfare gains from liberalization	0.99	1.12	0.88

that is, an increasing taxation of capital and a decreasing taxation of labor.

The final sensitivity analysis is with respect to the upper bound on the profit tax rate. The last column of Table 5 reports the simulation results when the upper bound is reduced to $\bar{\tau}^P = 0.36$ (in the baseline model the upper bound is 0.42). In changing $\bar{\tau}^P$ I also change $\bar{\tau}^A$ so that the implicit tax rate on labor in the autarky equilibrium matches the calibration target of 35 percent. The reduction in the upper bound reduces the welfare gains from capital liberalization. This is because the reduction in the profit tax rate is smaller. In the baseline model the profit tax rate falls by 17.5 percentage points while with the new parameterization it falls by 15.5 percentage points. The upper bound $\bar{\tau}^P$ determines the importance of the lack of policy commitment for the equilibrium policies. When the upper bound is high, the inefficiencies induced by the lack of policy commitment are also higher and the welfare benefits induced by capital liberalization are larger.

8 Conclusion

Studies in the optimal taxation literature conclude that the taxation of capital should be minimized in the long-run. There are several obstacles to the implementation of this normative recommendation. Among them is the lack of government commitment. Due to time-consistency problems, equilibrium policies over-tax capital and are inefficient. The liberalization of capital markets reduces the incentive to tax capital and improves welfare. The welfare gains are evaluated to be in the order of 1 percent of consumption. These gains will not be achieved if the integrating countries coordinate their fiscal policies as recommended by the October 1997 communication from the European Commission to the European Council.

A Appendix: Corporate tax rates

Table 6: Statutory corporate tax rates in the European Union Countries, 1979-2003.

	AUS	*BEL*	*FIN*	*FRA*	*GBR*	*GER*	*GRE*	*IRE*	*ITA*	*NET*	*POR*	*SPA*	*SWE*	*MEAN*
1979			60	50	52	62	43	45	36	48		33		48
1980			60	50	52	62	43	45	36	48		33		48
1981			60	50	52	62	43	10	36	48		33		44
1982	61		60	50	52	62	43	10	39	48	55	33	60	48
1983	61	45	60	50	50	63	43	10	46	48	55	33	60	48
1984	61	45	60	50	45	63	44	10	46	43	55	35	60	48
1985	61	45	60	50	40	63	44	10	46	43	55	35	60	47
1986	61	45	60	45	35	63	44	10	46	42	55	35	52	46
1987	61	43	50	45	35	63	44	10	46	42	46	35	52	44
1988	61	43	50	42	35	63	44	10	46	42	46	35	52	44
1989	39	43	50	39	35	63	40	10	46	35	40	35	57	41
1990	39	41	40	37	34	58	40	10	46	35	40	35	45	38
1991	39	39	40	34	33	59	40	10	48	35	40	35	30	37
1992	39	39	36	34	33	59	40	10	48	35	40	35	30	37
1993	39	39	25	33	33	58	40	10	52	35	40	35	30	36
1994	34	40	25	33	33	54	40	10	52	35	40	35	28	35
1995	34	40	25	37	33	57	40	10	52	35	40	35	28	36
1996	34	40	28	37	33	57	40	10	53	35	40	35	28	36
1997	34	40	28	42	31	57	40	10	53	35	40	35	28	36
1998	34	40	28	42	31	56	40	10	41	35	37	35	28	35
1999	34	40	28	40	30	52	40	10	41	35	37	35	28	35
2000	34	40	29	38	30	52	40	10	41	35	35	35	28	34
2001	34	40	29	36	30	38	38	10	40	35	35	35	28	33
2002	34	40	29	35	30	38	35	10	40	35	33	35	28	33
2003	34	34	29	35	30	40	35	13	38	35	33	35	28	32

Source: The Institute for Fiscal Studies, `http://www.ifs.org.uk`

Notes: For countries using different tax rates, the manufacturing rate is chosen. Local taxes (or the average across regions) are included where they exist. Any supplementary taxes are included only if they apply generally. Tax rates for Denmark and Luxembourg are not reported by The Institute for Fiscal Studies.

B Appendix: Computational procedure

The numerical procedure uses a global method that follows the steps used in Section 4 to define a policy equilibrium after approximating the policy function $\Psi(\mathbf{s})$. The aggregate states are the assets owned by the residents of the two countries, that is, $\mathbf{s} = (A_1, A_2)$.

Assuming that government spending is sufficiently large, the personal capital income tax rates are set to their maximum value $\bar{\tau}^A$ (see property 2 in Section 4.3). The use of the governments' budget constraints allows the determination of the labor tax rates τ_i^L residually. The

policy function $\Psi(\mathbf{s})$ can then be reduced to a mapping that returns (τ_1^P, τ_2^P) given the aggregate states $\mathbf{s} = (A_1, A_2)$.

The policy function $\Psi(\mathbf{s})$ is approximated by forming a two-dimensional grid for the states $\mathbf{s}$ and assigning the values of (τ_1^P, τ_2^P) on each grid point. The grided data is then joined with quadratic polynomial interpolation. The detailed steps are described below.

1. Form a two dimensional grid for (A_1, A_2). Each point of this grid is indexed by j. Given N the number of grid points for each asset A_i, the two dimensional grid contains N^2 points. Therefore, $j = 1, ..., N^2$.

2. Guess the policy function $\Psi(\mathbf{s})$. This requires the guess of $2 \times N^2$ numbers (the profit tax rate chosen by each country at each grid point).

3. For each grid point j, solve for the policy game between the two countries taking as given the guessed policy rule $\Psi(\mathbf{s})$. This requires the following steps:

   (a) Construct a procedure that solves for the function $\hat{V}_i(A_1, A_2, \tau_1^P, \tau_2^P; \Psi)$ defined in (13), for any initial values of (A_1, A_2) and (τ_1^P, τ_2^P) and given the policy rule Ψ determining future tax rates. Given the initial conditions, this procedure finds the whole transition dynamics using the first order conditions (11) and (12) and the terminal condition $A_{i,T+1} = A_{i,T}$ (in addition to all the equilibrium conditions). The terminal condition is based on the assumption that after T periods the economy is sufficiently close to the new limiting equilibrium or steady state. $T = 50$ gives a good approximation. Notice that the limiting equilibrium depends on the initial conditions. To solve for the non-linear system of equations this procedure uses the FORTRAN routine NEQNF. Once we have the solution for the whole sequence of consumption and working hours, we can compute the value function $\hat{V}_i(A_1, A_2, \tau_1^P, \tau_2^P; \Psi)$ as the discounted sum of per-period utilities.

   (b) Given the procedure that returns $\hat{V}_i(A_1, A_2, \tau_1^P, \tau_2^P; \Psi)$, guess the optimal tax rate

for country 1. This guess is denoted by $\hat{\tau}_1^g$. Given the tax rate of country 1, solve for the optimal tax rate of country 2, that is, $\hat{\tau}_2^P = \arg\max_\tau \hat{V}_2(A_1, A_2, \hat{\tau}_1^g, \tau; \Psi)$. Then solve for $\hat{\tau}_1^P = \arg\max_\tau \hat{V}_1(A_1, A_2, \tau, \hat{\tau}_2^P; \Psi)$. These maximization problems are solved using the FORTRAN routine UVMIF. The solution of the policy game must satisfy $\hat{\tau}_1^P = \hat{\tau}_1^g$. If not, update the guess $\hat{\tau}_1^g$ until the error is sufficiently small.

4. The solution to the policy game returns the tax rates $(\hat{\tau}_{1,j}^P, \hat{\tau}_{2,j}^P)$ for each grid point $j = 1, ..., N^2$. These tax rates are used as new guesses for the values of the policy rule $\Psi(\mathbf{s})$ at the gridded points. The procedure is then restarted from step 2 until convergence, that is, $(\hat{\tau}_{1,j}^P, \hat{\tau}_{2,j}^P) \simeq \Psi(A_{1,j}, A_{2,j})$ for all $j = 1, ..., N^2$.

Once the procedure has converged and we have the approximated policy rule Ψ, a steady state equilibrium is computed by solving the model for a sufficiently large number of periods starting from the desired initial conditions (A_1, A_2). The steady state is the equilibrium to which the economy converges. In the case of autarky the policy rule is trivial. Based on property 1 of Section 4.3, we can simply set $\Psi(A_1, A_2) = (\bar{\tau}^P, \bar{\tau}^P)$ for all A_1 and A_2.

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