

The Effects of Labor Migration on Optimal Taxation:^{*} An International Tax Competition Analysis

Soojin Kim [†]

November 2013

Abstract

Two key determinants of optimal tax policies in open economies are the mobility of factors of production, capital and labor; and strategic interaction between governments in setting their policies. This paper develops a two-country, open-economy model with labor mobility and a global financial market to study optimal taxation. Governments engage in tax competition in which they choose a labor income tax code and a capital income tax rate. A quantitative application of the model to the United Kingdom (UK) and Continental European countries (CE) shows that factor mobility and competition between governments are indeed crucial in the design of optimal policies. Incorporating labor mobility leads to a divergence in the optimal tax system: Unlike in an economy with only capital mobility, where both countries use similar capital income tax rates, the optimal capital income tax rate in the UK is lower than that in the CE when both capital and labor are mobile. This is due to the differences in productivity between the two countries. In the calibrated economy, the UK, whose productivity is higher than that of the CE, attracts more labor through migration. Thus, the welfare-maximizing level of capital in the relatively small CE is lower than that in the UK. Moreover, I find that capital income tax rates are higher with competition. With competition, both governments lower capital income tax rates, rendering the marginal benefit of a lower tax rate to decrease. The steady-state welfare gain from implementing the Nash equilibrium policies is about 11 percent of consumption of the *status quo* economy.

JEL Codes: E24, F22, H21.

Keywords: Optimal Taxation, International Migration, Human Capital, Tax Competition.

^{*}This article is based on a chapter of my doctoral dissertation at the University of Pennsylvania. I am grateful to Ufuk Akcigit, Hal Cole, David Dillenberger, Hanming Fang, Dirk Krueger, Serena Rhee, Andrew Shephard, Dave Weiss, seminar participants at various institutions, and conference participants at EconCon 2012, 2013 Midwest Macro Meeting (UIUC), and 2013 North American Summer Meeting of the Econometric Society (USC) for helpful discussions on the paper. All remaining errors are mine.

[†]Department of Economics, Purdue University, 403 W. State St., West Lafayette, IN 47907. soojink@purdue.edu.

1 Introduction

In September of 2012, French president François Hollande introduced his plans for a 75 percent income tax on “the rich.”¹ The announcement immediately incited concerns about the exodus of talented workers from France. These concerns were not unfounded: While awaiting the French tax reform earlier in June, David Cameron, the Prime Minister of the United Kingdom, had offered to “roll out the red carpet and welcome more French businesses to Britain.”²

The controversy caused by this French legislation (and Britain’s ready response to it) is an example of the recent policy debates taking place in many countries. These debates have centered on the issues surrounding the optimal degree of income redistribution through taxation, and the competition between governments in attracting scarce resources – capital and high-skilled labor. Although a progressive tax system provides income insurance to households, it can lead to a flight of resources in open economies. Thus, governments may engage in tax competition in an effort to attract the factors of production. This paper studies the optimal labor income tax *codes* (particularly, progressivity) and capital income tax rates in economies confronting international factor mobility and competition between governments.

Although economists have studied the effects of capital *or* labor mobility on taxation in an international tax competition framework, a joint analysis of the mobility of *both* factors on optimal taxation has not been conducted. However, since the marginal product of capital (labor) is increasing in labor (capital), considering both factors is important: A tax system that induces accumulation of one factor increases the marginal product of the other. Thus, optimal policies should weigh the tradeoffs of taxing capital and labor. Moreover, human capital can differ in its quality (skilled and unskilled labor, for example), and the returns to investment are heterogeneous across households. Therefore, when countries differ in the relative efficiency of unskilled and skilled labor in production, the optimal progressivity of labor income tax codes are affected by the possibility of labor mobility. Thus, the *progressivity* of the labor income tax code is an important component in the design of government policies in open economies.

Further, in this paper, I capture one of the key aspects of optimal taxation in open economies: the strategic interaction between governments. Empirical studies show that the migratory response to tax rates can be large for both capital and labor,³ which can lead to tax competition between governments. Quantitative studies of optimal taxation have abstracted from these strategic concerns by the governments, which I take into account in this paper.

¹On December 29, 2012, however, France’s Constitutional Council ruled that the policy was unconstitutional. In response to the ruling, Prime Minister Jean-Marc Ayrault said that the government “will present a new proposal in line with the principles laid down by the Constitutional Court.”

²David Cameron made this comment at the G20 summit in Mexico on June 19, 2012. (Murphy, Richard. “In wooing French tax exiles, Cameron makes a mockery of democracy,” *The Guardian*, 19 June 2012.)

³Altshuler et al. (1998) finds the elasticity of capital with respect to tax rate of around -2.7. Hines (1997, 1999) and Hines and Rice (1994) also report high degree of responsiveness of Foreign Direct Investment with respect to tax rates, internationally and across states in the U.S. Gorter and Parikh (2000) uses countries in the European Union and finds the elasticity to be around -4.3. On the labor side, Kleven et al. (2012) finds that a one percent increase in take-home pay increases migration of the skilled labor by 1.5 percent, which is based on Danish micro data.

In order to address these issues, I build a two-country, open-economy model where governments compete in setting their tax systems. Countries in the model differ in their production technologies – the relative efficiency of unskilled and skilled labor – and human capital production technologies.

Households, who reside in one of the countries, live for two periods – one as a child and the other as a parent – and are altruistic towards their child. The parents, who make economic decisions, are heterogeneous with respect to their skill level (skilled or unskilled), assets, and idiosyncratic labor productivity, among others. They make consumption and leisure decisions, leave bequests, and invest in the child’s human capital, which increases the probability that the child becomes skilled. At the end of life, after observing a migration (dis)utility shock, households make migration decisions. Households in the economy can freely trade international bonds. However, they face incomplete financial markets: Explicit insurance market for idiosyncratic labor risk does not exist. Incorporating heterogeneity across households makes the model suitable for the analysis of the differential welfare impacts of tax systems across households. Moreover, the model provides a framework with which I can discuss the tax-induced migration decisions of the skilled and the unskilled, which has been important policy debates in recent years.

The tax competition framework in this paper follows that of Mendoza and Tesar (2005). Governments engage in a *one-shot* tax competition game,⁴ where they maximize the steady-state welfare of households residing in their countries, by choosing a labor income tax *code* (allowing for progressivity) and a capital income tax rate. In doing so, the governments *take as given* the other country’s tax system. They finance a fixed amount of revenue *per capita*, with which they provide public education⁵ and transfer back the rest of the proceeds to households in a lump-sum fashion.

In the quantitative analysis, I apply the model to the United Kingdom (denoted as the “UK” hereafter) and Continental European countries (an aggregate of France, Germany, Italy, and Spain, denoted as the “CE” hereafter). These are the countries between which no immigration barriers exist, thus making them suitable candidates for a discussion of optimal taxation in presence of labor mobility.⁶ I calibrate the parameters to match the observed economic outcomes and migration statistics (in 2000), taking the *status quo* tax systems and public education spending from data as given. By following this route, I implicitly assume that the currently observed tax systems in the countries under consideration are not yet the result of the tax competition game in the model economy. I follow this approach since the observed tax system in 2000 had their origins in previous decades in which labor mobility rates were dramatically lower than they are now.⁷ Thus, the view taken here is that the increased labor mobility and competition between the governments have not

⁴I assume that they are able to commit to their policies, by for example, an institutional arrangement. Klein, Quadrini, and Rios-Rull (2005) study time-consistent taxation in open economies.

⁵Since I model the endogenous accumulation of human capital and the impact of tax policies on skill distribution, public education is an important part of government policy in this analysis.

⁶Therefore, I abstract from immigration policy choices of the governments. Kennan (2013), on the other hand, studies the effects of removing restrictions on immigration.

⁷In fact, between 1987 and 2004 in EU-15, the total number of foreign residents grew 48.7% (14.4 million to 21.4 million). Within EU-15, the increase is higher at 64.1 % (9.2 million to 15.1 million). So, we see a large increase in foreign residents in countries in the EU.

yet fully shaped the tax systems in these countries, but will do so in the future. The questions I aim to answer in the quantitative analysis are: (a) Given the fundamentals and mobility patterns in 2000, if governments compete with each other non-cooperatively, what would be their tax systems in the long run?; (b) Does labor mobility matter for this result? and; (c) What if there were no strategic interaction between the governments?

In the calibration exercise, I find that the UK has higher overall productivity and relative efficiency of skilled labor in production than the CE does. These asymmetries are necessary to match observed higher skill premium and higher percentage of skilled (which I define as college graduates in the data) in the UK compared to the CE. Based on these parameters, I find the Nash equilibrium of the tax competition game, and conduct two counterfactual analyses to understand the effects of labor mobility and competition.

In the Nash equilibrium, the UK implements a progressive labor income tax code (average labor income tax rate is 52 percent) in conjunction with capital income subsidy of 32 percent. On the other hand, the CE levies a 6 percent tax on capital income, and uses a less progressive labor income tax code relative to the UK (with an average of 50 percent). The capital (labor) income tax rates in the Nash equilibrium are markedly lower (higher) than those in the *status quo*: In the *status quo*, the UK levies a 48 percent and (on average) 24 percent tax on capital and labor income, respectively, while the analogous numbers are 28 percent and 30 percent for the CE.

There are several features of the Nash equilibrium tax systems that are worth discussing. First of all, in the Nash equilibrium, both countries use lower taxes on capital, as capital is more mobile than labor.⁸ In this economy with mobile labor, a low capital income tax rate not only attracts capital, but also labor, indirectly through higher wages.⁹ Secondly, the capital income subsidy result is consistent with the findings in Davila et al. (2012): In economies with incomplete markets and large asset inequality, the laissez-faire equilibrium might feature under-accumulation of capital. Therefore, governments might find it optimal to subsidize capital. Furthermore, since I allow for the use of progressive labor income tax code, both governments use progressivity to compensate for the missing private insurance markets for idiosyncratic labor risk.¹⁰

To further analyze the Nash equilibrium results, I conduct two analyses: One is aimed at understanding the effects of competition, and the other, the effects of labor mobility on optimal taxation. First, to study how competition affects optimal taxation, I let the UK (CE) *unilaterally* reform its tax system, taking as a given the *status quo* tax system of the other. This is in contrast to the benchmark Nash results, where countries strategically interact and compete in setting their tax systems. In the unilateral reform, I find that the UK and CE act more aggressively in setting their policies: The capital income tax rates are *lower* in the unilateral reform case. This is driven by the existence of the global financial market in the large open economy model: The benefit of a lower capital income tax rate is higher when the other country's capital income tax rate is higher,

⁸In the model, capital is freely mobile (through a global financial market), but households face migration cost shock upon migrating to the other country.

⁹This is due to the fact that marginal product of labor is increasing in capital.

¹⁰This point was also discussed in Conesa and Krueger (2005).

which is the case in the *status quo*.

Second, to isolate the effects of labor mobility, I compare the Nash equilibrium tax systems in an economy with *only* capital mobility to the benchmark result (*both* capital and labor mobility). The Nash equilibrium capital income tax rates between the UK and CE are similar in the economy where only capital is mobile. However, as countries open up to labor mobility, the capital income tax rates diverge: The UK lowers its capital income tax rate further, while the CE does the reverse. When labor is mobile, the UK, whose productivity is higher, becomes a country with more population. Therefore, the *welfare-maximizing* level of capital in the UK is higher than that in the CE; thus, the UK lowers its capital income tax upon opening up to labor mobility, while the CE does the reverse.

Finally, I find that implementing Nash equilibrium policies leads to the steady state welfare gain of 11 and 13 percent of consumption in the *status quo* economy in the UK and CE, respectively. Under the Nash equilibrium policies, after-tax return to capital increases since capital income tax rates are lower. As both countries increase the progressivity of the labor income tax code, households (i) reduce human capital investment, lowering fraction of the skilled workforce; (ii) work less; and (iii) the unskilled benefit more from the reform than the skilled do, by about twofold. Furthermore, there is a 5% increase in the skilled labor residing in the UK (out of global skilled workforce), despite its highly progressive labor income tax system. This is due to high level of capital stock in the UK, which increases wages, leading to higher after-tax labor income for the skilled labor. Incorporating mobility of *both* factors of production, therefore, is essential for the determination of the optimal tax system, as with only capital (labor) mobility, we cannot capture the indirect effects of lowering capital (labor) tax rates on the mobility of labor (capital).

Related Literature This paper is located at the intersection of several strands of literature, including that on (international) tax competition, optimal taxation of capital and labor, and the effects of labor mobility on macroeconomic outcomes.

There is a wide literature that studies international and interjurisdictional tax competition in capital and labor.¹¹ With regard to the capital income tax dimension, Gordon (1986) and Razin and Sadka (1991) theoretically study two different types of capital income taxation: source versus residence-based taxation, as well as taxation of different kinds of capital. As for labor income tax competition, Mirrlees (1982) and Bhagwati and Hamada (1982) are seminal papers that focus on the taxation of foreign and domestic labor income in less-developed countries. Razin and Sadka (2011, 2013) also conduct analytical studies of labor income tax competition, but take the flow of migrants as exogenous and abstract from capital mobility.¹² Fiscal federalism literature¹³ is also concerned with the welfare impacts of interjurisdictional tax competition. There, the regional

¹¹There are also tax competition papers that deal with tax on consumption goods (Chari and Kehoe (1990) and Kanbur and Keen (1993), for example) or corporate income (Devereux et al. (2008), for example).

¹²The model in Tiebout (1956) also studies labor mobility and its impact on the provision of public goods in multiple communities.

¹³For a review of interjurisdictional competition in federalism literature, see Oates (1999).

governments focus on providing public goods, while facing the threat of the flight of capital or labor. This paper complements these literature by analyzing mobility of both factors within a model, and quantitatively analyzing the effects of the mobility on optimal taxation.

The paper that most closely relates to the framework I use in this paper is a 2005 study by Mendoza and Tesar. In it, the authors study a tax competition game in a dynamic general equilibrium model with capital mobility. A capital income tax rate is chosen to maximize welfare in the balanced growth path, while the labor income tax (or a consumption tax) is a tool used to ensure fiscal solvency. They find that in the UK and Continental Europe (which they define as France, Germany, and Italy),¹⁴ the Nash equilibrium is close to the observed tax rates, when the labor income tax is used to resolve fiscal solvency; there is no race to the bottom of capital income tax rates. This result is driven by the distortionary effects of using labor income tax. The key difference in their calibration and mine is that in my model, the Frisch elasticity is calibrated to be 0.3 (which is consistent with micro estimates found in Browning et al. (1999)), while under their calibration, the Frisch elasticity of labor supply is around 1.7; thus, distortions from taxing labor are higher in their model. What is interesting though is that, when consumption taxes are used to ensure fiscal solvency, they also see that in the Nash equilibrium, capital income is subsidized.¹⁵ Unlike Mendoza and Tesar’s analysis, this paper incorporates labor mobility, heterogeneity in households, and a possibility of using progressive labor income taxes to allow for a richer analysis of optimal policies in a tax competition framework.

The topics studied in this paper also intersect with the dynamic optimal taxation literature. Starting with Judd (1985) and Chamley (1986), dynamic optimal taxation has been widely studied, both theoretically and quantitatively. Most of these studies have been conducted in a closed economy, representative household framework. My model, on the other hand, studies taxation in large open economies, each of which feature incomplete asset markets and household heterogeneity.

Aiyagari (1995) studies optimal capital taxation in an incomplete markets model. He finds that governments can improve the welfare of households by taxing capital income, which induces households to decrease their precautionary savings. A more recent, related study by Davila et al. (2012) examines constrained efficiency in incomplete markets, which has implications for capital income taxation. They find that if the consumption-poor in an economy is relatively more labor income-rich than asset-rich, the constrained optimum has higher aggregate capital than the laissez-faire equilibrium – an argument for a lower (or negative) capital income tax rate. Also related is a study of the dynamic optimal taxation in large open economies, analyzed by Gross in a 2012 paper.¹⁶ He finds that when large open economies use a territorial tax system, a zero capital income tax rate in the long run is still optimal. Among others, Conesa et al. (2009) quantitatively studies optimal taxation allowing for a progressive labor income tax system. They find that positive capital income tax is optimal, in an overlapping generations model. This paper complements the existing

¹⁴These countries are assumed to be identical in their fundamentals.

¹⁵This is similar to the Nash equilibrium results of my model under *only* capital mobility.

¹⁶Ha and Sibert (1997) also study strategic capital taxation in large open economies. They distinguish between corporate and savings taxes, and find that capital importers set positive tax rates, while exporters subsidize capital.

literature by quantitatively studying the optimal taxation of both capital and labor in large open economies with incomplete markets.

Lastly, this paper both relates to and expands on existing studies of the effects of labor mobility on macroeconomic outcomes. Two studies by Klein and Ventura (2007, 2009) use a general equilibrium model to quantify the the aggregate effects of removing barriers to labor mobility. On a similar note, Benhabib and Jovanovic (2011) solve the social planning problem of maximizing the welfare of rich and poor country residents. These papers find big gains from higher mobility. However, they do not consider the taxes nor human capital accumulation that I endogenize in this paper.¹⁷ Enriching the analysis to allow for the effects on human capital yields important implications for the impact of taxes on labor mobility and skill distribution in both countries.

The paper proceeds as follows. In the next section, I describe the model in detail. The model description comprises defining the competitive equilibrium of the open-economy model and the Nash equilibrium of the tax competition game between the governments. Following the model, I present the calibration strategies and results in section 3. In section 4, quantitative results are discussed in several steps. I first analyze key household behaviors: the human capital investment and migration decisions. Then, in section 4.2, I discuss the effects of changes in the tax code on aggregate outcomes, which provides insights into the results of the unilateral reforms of the UK and CE governments. Next, I present the Nash equilibrium policies and discuss the effects of competition and aggregate outcomes in the Nash equilibrium. In section 4.4, I compare the optimal taxation results with *only* capital mobility and with *both* capital and labor mobility to study the effects of labor mobility in isolation. I conclude in section 5.

2 The Model

In this section, I describe the model and define the competitive equilibrium given policy¹⁸ and Nash equilibrium of the tax competition game.

2.1 Model Description

I consider a two-country, large open-economy model where both physical and human capital are endogenously accumulated and mobile. Time is discrete and there is a fixed measure one of total households (the sum of households residing in both countries is constant). Agents in the economy live for two periods, one as a child and one as a parent, but only make decisions as a parent.

¹⁷There are also papers that relate immigration to resolving fiscal imbalances in the US. Storesletten (2000) uses a general equilibrium overlapping generations model to capture the fiscal impact of immigration and claims, that immigration can be used as a tool to solve fiscal imbalance in the US. Auerbach and Oreopoulos (1999), on the other hand, finds a very small fiscal impact from immigration.

¹⁸I formulate the dynamic problem recursively and conduct a steady state analysis. Thus, I abstract from time subscripts in the notations below.

Endowments and Preferences. Households (parents) are endowed with one unit of time which they can divide between leisure and work.

Preferences of households are assumed to be represented by

$$u(c, l) + \beta EV'$$

where c and l are consumption and labor hours, respectively. The term EV' represents the expected utility of the offspring, which is weighted by the altruism factor β .

Each household is heterogeneous in his country of residence (i), his child's ability (z), skill level of himself (θ), capital (k) and international bond (b) holdings, and idiosyncratic labor productivity shock (ε). I assume that there are two skill levels in this economy, skilled (s) and unskilled (u), thus $\theta \in \{s, u\}$.

The labor productivity shock ε is independently and identically distributed (i.i.d.) across time and households, and has distribution $\pi_\varepsilon(\varepsilon)$. In each period, a household with skill level θ and i.i.d. productivity shock ε , who works l hours, earns $w^i(\theta)l\varepsilon$ in country i .

When households decide to migrate to the other country, they incur a utility cost of moving h . The migration decision is made after the realization of the moving cost shock, which has a probability distribution function (pdf) of $f(h)$. In the model, I interpret h as incorporating both moving cost and location preference, and thus use location preference and moving cost interchangeably to denote h hereafter.

Human Capital Technology. Each household is born with his child's ability level $z \in [\underline{z}, \bar{z}]$. The ability level is persistent across generations and evolves stochastically according to $\pi(z'|z)$.

Human capital investment $\tilde{x}$ ¹⁹ increases the probability of becoming a skilled worker. Since I assume that public and private spending on education are perfect substitutes, $\tilde{x}$ refers to the *total* education spending (public and private). Probabilities of becoming a skilled or unskilled worker are represented by $Q(s|z, \tilde{x})$ and $Q(u|z, \tilde{x})$, where $Q(\cdot|z, \tilde{x})$ is continuous in z and $\tilde{x}$. Moreover, $Q_{z\tilde{x}}(s|z, \tilde{x})$ is positive, which implies that the return to human capital investment is higher for children with higher ability.

Production. Production requires three inputs: physical capital, unskilled labor, and skilled labor. I denote by K , capital, and U and S are the total amount of labor provided by unskilled and skilled households, respectively. The production function is represented by $F(K, U, S)$ and capital depreciates at rate δ .

Market Structure. Households cannot insure against idiosyncratic labor income risk by trading insurance contracts. However, they can participate in financial markets.

¹⁹In the current formulation of the model, human capital is accumulated through goods input (buying books, for example). Erosa and Koreshkova (2007), on the other hand, models human capital investment as human capital *services* purchased at the market wage rate.

There is a domestic capital market whose return is denoted as $1 + r^i$. Moreover, households can trade international bonds freely, with a gross return of R . I assume that households can participate in domestic capital market and international bonds market, but not in foreign capital market, which requires some discussion.

Financial market structures in open-economy models can take several forms, and each has important implications for the general equilibrium outcomes and optimal policies. If households have costless access to both domestic and foreign capital markets and pay taxes based on residence, the pre- and post-tax returns to capital in the two countries must be equalized in equilibrium. This is in marked contrast to observed differences in capital income tax rates across countries. In order to allow for the equilibrium capital income tax rates that differ across countries *and* for the existence of a global financial market (capital mobility), I follow Mendoza and Tesar (1998, 2005) who assume that households can only trade international bonds and invest in domestic capital markets. Under this market structure, after-tax returns to capital are equalized in equilibrium.²⁰ Therefore, even though capital cannot be invested in both countries, there will be reallocation effects of capital in response to changes in tax rates, not only in the home country, but also in the foreign country; this is the key mechanism necessary for the analysis in this paper.

Government Policy. Governments in this model have exogenous *per capita* expenditure requirements. They use the proceeds for providing public education (E^i) and transfer back the rest of the proceeds in a lump-sum fashion (TR^i). I restrict that the transfers must be greater than or equal to zero ($TR^i \geq 0$). Since with labor mobility, population size is endogenously determined, I denote by e^i and tr^i , per capita public education and lump-sum transfer provided by the governments. While I abstract from most public policies (or welfare programs) run by the governments, I explicitly model public education expenditure. Modeling public education expenditure is particularly important, since households make human capital investment decisions which depends on public expenditure. Moreover, in the quantitative analysis, I map the model into countries which have stark differences in their public and private education expenditure. I do not allow the governments to issue debt, and thus, they must satisfy a period-by-period budget constraint.

The sources of government revenue are labor and capital income taxes. The labor income tax code is denoted by $\tau(y; \bar{y})$: An individual who earns y in an economy where average labor earning is $\bar{y}$ faces a tax rate of $\tau(y; \bar{y})$. The purpose of this function is to allow for the progressive labor income tax code, present in many countries. In this economy, capital is taxed at a flat tax rate of τ_k , and I denote as τ^i the tax system $\{\tau(y; \bar{y}), \tau_k\}$ in country i .

Moreover, I also assume that governments levy capital income tax on returns from the domestic capital market (k), but not on returns from international bonds (b). In most countries, returns from participating in domestic and international capital markets are treated the same. However, due to no-arbitrage conditions, tax rates on international bonds must be the same in equilibrium.

²⁰As pointed out in Gross (2012), the equilibrium condition of this financial market structure is the same as the one in which households can invest in both countries and countries levy source-based capital income taxes.

This would imply that different tax rates on capital income cannot be supported. One way of circumventing this problem is to assume that countries levy different taxes on international bond returns than they do on domestic capital income, with the restriction that tax rates on bonds are same across countries. Under the current formulation, I assume that tax rates on interest from international bonds are zero in both countries.

These are the restrictions on the kinds of tax instruments that governments use that I impose. Therefore, in the tax competition game, governments optimize their use of policies *within* the tax functions that I describe, taking per capita public education expenditure e^i and transfers tr^i as given.

Timing. The model timing is as the following (summarized in Figure 1).

A household enters its current period with the state variables $(i, z, \theta, k, b, \varepsilon)$. Each individual (household) residing in country i becomes a parent with the child's ability z , his own human capital θ (skilled or unskilled), capital goods k and international bonds b bequeathed from his parents, and productivity shock ε . Households provide labor (l), consume (c), invest in human capital (x), purchase private capital (k'), and trade international bonds (b').

After the ability of the grandchild (z'), skill (θ') and labor productivity shock (ε') of the child, and location preference shock (h) are realized, households make migration choices.

2.2 Competitive Equilibrium of the Economy

This section contains a detailed discussion of the household problem, the firm problem, government budget constraint, and the definition of the competitive equilibrium, given an exogenous tax system in both countries.

Household Problem. Each household starts his parental life in country i with offspring's ability level (z), human capital (θ), assets bequeathed from parents (k, b), and the i.i.d. labor productivity shock (ε). As mentioned above, households can bequeath assets as domestic capital (k) or international bonds (b). However, due to the existence of a global financial market, the (after-tax) returns to assets must be equalized in equilibrium. Therefore, the sufficient statistic for the household problem is $a = k + b$, and the choice variable, a' . The household problem can then be stated as

$$V^i(z, \theta, a, \varepsilon) = \max_{l, c, x, a'} u(c, l) \tag{1}$$

$$\begin{aligned} & + \beta \sum_{z', \theta', \varepsilon', h} \Xi(z, x, z', \theta', \varepsilon', h) \left\{ \mathbb{E}_h \max \left[\begin{array}{c} V^i(z', \theta', a', \varepsilon'), \\ V^j(z', \theta', a', \varepsilon') - h \end{array} \right] \right\} \\ \text{s.t.} \quad & c + x + a' = (1 - \tau(y))y + Ra + TR^i, \tag{2} \end{aligned}$$

$$y = w^i(\theta)l\varepsilon, \tag{3}$$

$$a' \geq 0, \quad c \geq 0, \quad 0 \leq l \leq 1 \tag{4}$$

where $\Xi(z, x, z', \theta', \varepsilon', h) \equiv \pi(z'|z)Q(\theta'|z', x + E^i)\pi_\varepsilon(\varepsilon')f(h)$.

Each household (parents) chooses the optimal level of labor hours (l), consumption (c), human capital investment (x), and total bequest (a') that maximizes his utility. Utility is derived from consumption and leisure today and the expected value of the child's utility in the future. The term $\Xi(z, x, z', \theta', \varepsilon', h)$ reflects the future expectations about realization of abilities (z'), skill level (θ'), i.i.d. labor productivity shock (ε'), and migration cost shock (h). The ability of the grandchild evolves stochastically, conditional on the ability of the child through $\pi(z'|z)$, and the skill level of the child is a function of the child's ability (z') and the sum of human capital investment by parents (x) and public education expenditure (E^i). I assume that private and public investment are perfect substitutes, and therefore, the probability of becoming a skilled worker is $Q(s|z, x + E^i)$. Moreover, the i.i.d. productivity shock (ε') is taken into account for evaluating the future value function, as well as moving cost (h), which has a pdf of $f(h)$.

The second part of the household objective function (1) includes the max operator that reflects migration decisions of the households. Although all economic decisions of the parents are made *prior* to the decision of migration, households only migrate *after* all realizations ($\{z', \theta', \varepsilon', h\}$) have been made. I also assume that the migrants do not face any depreciation in their productivity, following Bell (1997), who does not find any wage differential between immigrants and natives in the long run.

Households maximize their lifetime utility subject to constraints (2)–(4). The budget constraint of the household is represented by (2). The left-hand side represents possible expenditures – consumption, human capital investment, and physical capital investment (bequests) – and the right-hand side represents sources of income – after-tax labor income, assets, and transfers from the government. Equation (3) specifies labor income of the households, and equation (4) states that parents cannot borrow against the future earnings of their child (they can only leave zero or positive levels of assets). Consequently, parents have two ways of leaving their wealth to their offspring: they can either leave assets or invest in the human capital of their child to increase the child's labor earnings.

From hereafter, for simplicity, I denote as $\mathbf{s}$, the vector of state variables ($z, \theta, a, \varepsilon$), and $\Phi(\mathbf{s})$, the measure of households of type $\mathbf{s}$.

Firm Problem. Firms in country i produce goods using unskilled and skilled labor and capital, and a constant returns to scale production function F given market wage rates and rental rate of capital

$$\max_{K^i, U^i, S^i} F(K^i, U^i, S^i) - (r^i + \delta)K - w_u^i U^i - w_s^i S^i, \quad (5)$$

where δ is the depreciation rate of capital.

This implies that in equilibrium, factor prices satisfy

$$r^i = F_k(K^i, U^i, S^i) - \delta \quad (6)$$

$$w_u^i = F_u(K^i, U^i, S^i) \quad (7)$$

$$w_s^i = F_s(K^i, U^i, S^i). \quad (8)$$

Government Budget Balance. Governments use labor and capital income tax to provide per capita public education e^i and transfer back tr^i to households in a lump-sum fashion. They balance their budget every period, and thus the government budget balance condition reads as:

$$e^i \int_{\mathbf{s}} d\Phi^i(\mathbf{s}) + tr^i \int_{\mathbf{s}} d\Phi^i(\mathbf{s}) = \int_{\mathbf{s}} y^i(\mathbf{s}) \tau^i(y^i(\mathbf{s})) d\Phi^i(\mathbf{s}) + r^i \tau_k^i K^i, \quad tr^i \geq 0. \quad (9)$$

Governments cannot levy lump sum taxes, i.e., $tr^i \geq 0$. Moreover, since governments tax capital at a flat rate τ_k , the sufficient statistic for obtaining the total tax proceeds from capital income is total private capital (K^i) in each country.

Market Clearing. Market clearing conditions for the markets for goods and bonds are:

$$\sum_{i=1,2} \left(F(K^i, U^i, S^i) + (1 - \delta) K^i \right) = \sum_{i=1,2} \left(C^i + X^i + K'^i + E^i \right) \quad (10)$$

$$B^1 + B^2 = 0, \quad (11)$$

where

$$C^i = \int_{\mathbf{s}} c^i(\mathbf{s}) d\Phi^i(\mathbf{s}), \quad (12)$$

$$X^i = \int_{\mathbf{s}} x^i(\mathbf{s}) d\Phi^i(\mathbf{s}), \quad (13)$$

$$\begin{aligned} A^i &= \int_{\mathbf{s}} a^i d\Phi^i(\mathbf{s}) \\ &= K^i + B^i, \end{aligned} \quad (14)$$

$$U^i = \int_{z,a,\varepsilon} l^i(z, u, a, \varepsilon) \varepsilon d\Phi^i(z, u, a, \varepsilon), \quad (15)$$

$$S^i = \int_{z,a,\varepsilon} l^i(z, s, a, \varepsilon) \varepsilon d\Phi^i(z, s, a, \varepsilon), \quad (16)$$

and K^i and B^i are aggregate capital and bonds in country i . As I noted in the previous section, since the sufficient statistic in the household problem is the amount of assets bequeathed (a), but not its allocation in private capital (k) and bonds (b), there is an indeterminacy of the capital and bond position *at the household level*. However, by strict concavity of the production function, for a given equilibrium price of capital r^i and aggregate labor U^i, S^i , there is a unique level of *aggregate*

capital such that the equilibrium price condition (6) is satisfied. This condition pins down the level of aggregate capital (K^i) in both economies, and from A^i , I back out aggregate bond positions using $B^i = A^i - K^i$.

Now, I define a stationary competitive equilibrium of this economy, given government policy in country i , $\{e^i, tr^i\}$, and the set of government policies, $\{\tau^1, \tau^2\}$.

Definition 1 *Given an exogenous level of public education expenditure per capita $\{e^1, e^2\}$, transfers per capita $\{tr^1, tr^2\}$, and tax policies $\{\tau^1, \tau^2\}$, a stationary competitive equilibrium consists of value functions for households, V^i ; policy functions for households, $\{c^i, l^i, x^i, a'^i\}$; production plans for the firms, $\{K^i, U^i, S^i\}$; prices, $\{R, r^i, w_u^i, w_s^i\}$; and measures, Φ^i , in both countries $i \in \{1, 2\}$, such that:*

- (i) *households maximize given prices and policies: value functions solve (1) subject to constraints (2)–(4) with $\{c^i, l^i, x^i, a'^i\}$ as associated policy functions;*
- (ii) *firms maximize given prices and policies: prices $\{r^i, w_u^i, w_s^i\}$ satisfy (6)–(8);*
- (iii) *government budget balance condition (9) is satisfied;*
- (iv) *market clearing conditions (10) and (11) are satisfied with the associated aggregate variables defined in (12)–(16); and*
- (v) *Φ^i is derived from the policy functions of households and probability distribution for i.i.d. labor productivity shocks.*

Thus far, I defined the stationary competitive equilibrium of the economy for given tax systems in both countries. In the next section, I describe how I model tax competition and define the Nash equilibrium of the tax competition game between the governments.

2.3 Tax Competition and Nash Equilibrium

Governments choose income tax function and a capital income tax rate that maximizes the steady-state welfare of households at the stationary equilibrium supported by the tax system, taking as given the other country's tax rates. They decide on their time-invariant tax rates (functions) in the beginning of the period that satisfy their budget constraints, and I assume that both governments can fully commit to the tax system.

The welfare function that the governments maximize can take several forms depending on the value they put on immigrants and emigrants. In this paper, I assume that governments have a utilitarian social welfare function over the population *residing in the country, at the time the tax system is chosen*. Thus, each government's social welfare function, given the stationary distribution of households $\Phi^i(\mathbf{s})$ and the welfare of households achieved in stationary equilibrium $V^i(\mathbf{s})$ is

$$\int_{\mathbf{s}} V^i(\mathbf{s}) d\Phi^i(\mathbf{s}). \quad (17)$$

While the social welfare criterion only captures the lifetime utility of the current residents, $V^i(\mathbf{s})$ includes the residents' potential utility from migrating to the other country in the future.

Moreover, the tax functions must be chosen so that they satisfy the governments' period-by-period budget constraints. Rather than using a fixed (regardless of population size) amount of government expenditure, I use a *per capita* tax revenue requirement. It captures that the revenues necessary to provide a given amount of government services increase with population, which is important in this model, since population size is determined *endogenously* when labor is mobile.

In the next, I formally define a Nash equilibrium of the tax competition game.

Definition 2 *A Nash equilibrium (non-cooperative equilibrium) of the tax competition game (given public education expenditures per capita $\{e^1, e^2\}$ and transfers per capita $\{tr^1, tr^2\}$) in this economy consists of a vector of government policies $\boldsymbol{\tau}^i$, and associated competitive equilibrium prices $\{R, r^i, w_u^i, w_s^i\}$, and allocations $\{c^i, l^i, x^i, a'^i\}$, and the stationary distribution of households in each country Φ^i for $i \in \{1, 2\}$ such that:*

- (i) *for each country i , $\boldsymbol{\tau}^i$ maximizes the steady-state welfare of the economy (17), taking as given the tax system of the other country, $\boldsymbol{\tau}^{-i}$; and*
- (ii) *for $\{\boldsymbol{\tau}^1, \boldsymbol{\tau}^2\}$, the resulting prices, allocations, and stationary distributions are a competitive equilibrium.*

Since this is a dynamic general equilibrium model with heterogeneous households and incomplete markets, it is difficult to derive analytical characteristics of the effects of changing tax rates on macroeconomic outcomes and the best response of the game. However, I briefly discuss some (qualitative) effects of changing labor and capital income tax rates.

In this model, lowering either capital or labor income tax rates attracts both factors: When capital income tax rate is lowered in one country (fixing the other country's tax system), the country attracts more capital, increasing marginal product of labor (wages), and thus indirectly labor migrates into the country. On the other hand, a lower labor income tax indirectly attracts capital, and increases incentives for labor hours and investment in human capital. Moreover, in equilibrium, no-arbitrage condition holds: After-tax returns to capital between the two countries are equalized, $(1 - \tau_k)F_k(K, U, S) = (1 - \tau_k^*)F_k(K^*, U^*, S^*)$. Thus, governments will balance the use of capital and labor income tax to provide the households with enough (dis)incentives to accumulate capital and provide labor. The extent to which taxes can be better employed as a tool for increasing the welfare of households, therefore, is not straightforward and must be solved numerically under a reasonable set of parameter values. That is the goal of the quantitative analysis conducted in the following section.

3 Calibration

I use the United Kingdom (UK) and Continental Europe (France, Germany, Italy, and Spain, hereafter referred to as the “CE”) as countries of interest for the quantitative analysis. The free movement of labor within countries in the European Union²¹ makes the UK and CE an appropriate choice for the tax competition analysis with labor mobility. Moreover, as presented in Table 1, the UK has a tax system and aggregate economic outcomes that differs considerably from the CE in consideration. Therefore, considering the UK and CE is a suitable division of the countries in the EU for calibration, and for the further analysis of the impact of free labor mobility on optimal taxation.

In calibration, I assume that the current policies (data) are not the result of the tax competition game in the model economy. Thus, I take as given the *status quo* policies, and find parameters to match equilibrium outcome of the model economy to the aggregate statistics in 2000. The reason behind this approach is that the tax systems in 2000 do not yet reflect high mobility rates and increased competition more prevalent in the recent decades. So, the Nash equilibrium of the tax competition game I present in Section 4 is the long-run prediction of tax policies given mobility rates and fundamentals in 2000.

In the following, I first summarize some of the relevant data statistics and public policies in the UK and CE in sections 3.1 and 3.2, after which I discuss the calibration strategy and parameter values in sections 3.3 and 3.4. I briefly describe computational algorithm in section 3.5.

3.1 Descriptive Statistics of the Macroeconomic Data in the UK and CE

Table 1 is a summary of descriptive statistics of the UK and CE.²²

For the CE data, I use weighted averages from France, Germany, Italy, and Spain. Weights are obtained using the relative sizes of GDP and population: 0.25, 0.35, 0.24, and 0.16 respectively for France, Germany, Italy, and Spain.

As shown in Table 1, the UK and CE have comparable GDP per capita. The UK has a higher skill premium, higher labor earnings inequality, and a higher percentage of college graduates. However, overall tertiary education spending is higher in the CE, with its public spending comprising about 75 percent of the total expenditure on tertiary education.

Intergenerational persistence in schooling is obtained from Causa and Johansson (2009). They use OECD data to obtain the percentage increase in probability of an offspring obtaining college education when his or her father is college educated, compared to those whose fathers only have upper-secondary education.²³

²¹By Article 45 Treaty on the Functioning of the European Union (ex 39 and 48), which states that: “1. Freedom of movement for workers shall be secured within the Community. 2. Such freedom of movement shall entail the abolition of any discrimination based on nationality between workers of the Member States as regards employment, remuneration and other conditions of work and employment.”

²²Statistics for individual countries in Continental Europe are summarized in the Appendix (Table 11).

²³They also report the same measure comparing fathers with college education and those with less than upper-secondary education. In the UK and CE, the probability premium is around 0.38 and 0.45 respectively (calculated

Migration-related statistics are obtained from OECD bilateral migration data. I calculate immigration stocks from the UK to the CE and vice versa, and find the percentage of college-educated immigrants among the migrants from the UK and CE. Positive selection is evident from data, as the percentage of college graduates among immigrants is 37.7 percent in the UK (36.4 percent in the CE), whereas the same statistic for the total population within the country is 25.7 percent (20.0 percent).

Next, I describe the *status quo* public policies in the UK and CE.

3.2 Public Policies in the UK and CE

Following Benabou (2002) and Heathcote et al. (2012), the after-tax labor income is assumed to take the following functional form:

$$\tilde{y} = a_0 y^{1-a_1}, \quad (18)$$

which is known to represent labor income tax systems in different countries quite well. The after- and before-tax labor income is represented by $\tilde{y}$ and y , respectively. The parameter a_1 denotes the degree of progressiveness. The average labor income *tax function* implied by the suggested tax relation is

$$\tau(y) = 1 - a_0 y^{-a_1}. \quad (19)$$

When a_1 is equal to zero, the labor income tax rate is flat at $1 - a_0$.

I use this tax function to obtain the *status quo* tax function from data of the UK and CE. Following Guvenen, et al. (2011), I use top marginal income rates and thresholds to impute tax rates at multiples of average wages. Then, using the functional form (19), I find estimates of a_0 and a_1 that minimize the distance between the imputed tax rates from data and the labor income tax function.

Given the average labor earnings in the economy $\bar{y}$, the average tax rate for those earning y in the UK and CE can be represented by the functions

$$\begin{aligned} \tau^{UK}(y) &= 1 - 0.7792 \left(\frac{y}{\bar{y}} \right)^{-0.0692}, \\ \tau^{CE}(y) &= 1 - 0.7196 \left(\frac{y}{\bar{y}} \right)^{-0.0970}, \end{aligned}$$

and Figure 2 plots them. The smaller value of a_0 and a greater absolute value of a_1 in the CE tax function imply a higher (in levels) and a more progressive labor income tax code in the CE than in the UK.

For capital income taxes, I use the effective average capital income tax rates from Carey and Tschilinguirian (2000) who calculate capital income taxes between 1991 and 1997, by dividing the sum of corporate income taxes and personal capital income taxes by net operating surplus.²⁴ The

as weighted average of France, Italy, and Spain. German data is not available.).

²⁴This is the method used in Mendoza et al. (1994).

capital income tax rates are 48 percent in the UK and 28 percent in the CE.²⁵

In the model, I allow governments to use their tax proceeds for public education. As will be clear in the next subsection, I will define the skilled labor as those who have graduated from college. Therefore, I use the percentages of GDP spent on tertiary education in the UK and CE as their *status quo* public education policies. The UK, which has a lower labor income tax rates with less progressive income tax code, spends 0.6 percent of GDP in providing tertiary education, whereas the CE spends 0.9 percent of GDP. In the *status quo*, the CE, whose labor income tax code is more progressive, provides more public education, which can offset the disincentives created by its tax policies. The rest of the tax proceeds are assumed to be transferred back to the public in a lump-sum fashion. These lump-sum transfers are meant to represent the governments' redistributive policies, which are not explicitly modeled in this paper.

3.3 Calibration Strategy

Given the labor and capital tax income systems and public education expenditure in the UK and CE, I find parameters to match equilibrium outcomes of the model economy to the observed data. In doing so, I allow for heterogeneity in the production and human capital production technologies in the UK and CE. All other parameters are chosen to match relevant statistics in the UK. I *simultaneously* calibrate the parameters and use them to quantitatively solve for the Nash equilibrium of the tax competition game. In the following, I describe functional form assumptions and mapping between parameters and equilibrium outcomes.

A. Production. The production function is represented by

$$Y^i = K^\alpha \left\{ (A_u^i U^\rho + A_s^i S^\rho)^{\frac{1}{\rho}} \right\}^{1-\alpha}.$$

It is Cobb-Douglas in capital and labor and labor input is a constant elasticity of substitution aggregate of unskilled (U) and skilled labor (S). Thus, the skill premium can be expressed as

$$\frac{w_s^i}{w_u^i} = \frac{A_s^i}{A_u^i} \left(\frac{U^i}{S^i} \right)^{1-\rho}.$$

The parameter α represents the capital share in production, while A_u and A_s are the country-specific efficiency of unskilled and skilled labor, and ρ controls the elasticity of substitution between unskilled and skilled labor (the elasticity of substitution is $\frac{1}{1-\rho}$).²⁶

This parametrization has several benefits when compared to a version which models only one

²⁵The trends in capital and labor income tax rates in the UK and CE over the last thirty years show that the UK had lower labor income tax rates and higher capital income tax rates than the CE. The trends of tax rates and capital and labor income tax rates of individual countries in the CE are reported in the Appendix.

²⁶The production function can be rewritten as

$$F(K, U, S) = z^i K^\alpha (\tilde{A}^i U^\rho + (1 - \tilde{A}^i) S^\rho)^{\frac{1-\alpha}{\rho}}, \quad (20)$$

kind of labor input. Most importantly, there is evidence of cross-country differences in the substitutability of skilled and unskilled labor.²⁷ In a model with labor mobility as this one, differences in relative efficiency of two kinds of labor have implications for the tax-induced efficiency gain from reallocation of labor across countries and optimal policies. Moreover, in quantitative application of the model, I define the skilled labor as the college-educated workers in the data. Thus, the skill premium (college premium) can be used as a target in the calibration exercise, as well as data on migration patterns for those with and without college education.

As is customary in the literature, I set capital share in production (α) to be 0.33. Another production function parameter, ρ , which controls the elasticity of substitution between skilled and unskilled labor, is set so that the CES is around 1.4 following Katz and Murphy (1992).

Taking as given capital share α and ρ , which controls elasticity of substitution between skilled and unskilled labor, I calibrate A_s^{UK} , A_u^{UK} , A_s^{CE} , and A_u^{CE} that represent the efficiency of skilled and unskilled labor in production within the model. Skilled labor in my model is defined as workers who have graduated from college, and unskilled labor, as those who have not. With this classification, productivities are normalized by letting $A_s^{UK} + A_u^{UK} = 1$. Then, using the college premium in the UK and CE, and the ratio of GDP per capita in the UK to the CE, values for A_u^{UK} , A_s^{CE} , and A_u^{CE} are determined. The estimates of the college premium are taken from a series of papers published as a part of the project “Cross Sectional Facts for Macroeconomists”²⁸. This calibration strategy is similar to the one used by Caselli and Coleman (2006), in which they estimate the parameters of the CES production function in different countries using skill premiums, capital level, and supply of skilled and unskilled labor.

The capital depreciation rate δ is chosen to match the capital-output ratio in the UK.

B. Utility Function. Households’ lifetime utility function is

$$u(c, l) + \beta \mathbb{E}V' = \frac{c^{1-\sigma} - 1}{1 - \sigma} - \eta \frac{l^{1+\frac{1}{\gamma}}}{1 + \frac{1}{\gamma}} + \beta \mathbb{E}V',$$

where c and l are consumption and labor hours, respectively. Under this specification, the theoretical Frisch elasticity of labor supply is γ .

I set the risk aversion parameter σ to be 2, leaving three parameters to be calibrated within

where $z^i = (A_u^i + A_s^i)^{\frac{1-\alpha}{\rho}}$, and $\tilde{A}^i = \frac{A_u^i}{A_u^i + A_s^i}$. Thus, differences in A_u^i and A_s^i can also be interpreted as differences in total factor productivity z^i , and efficiency of skilled and unskilled labor with a normalization ($\tilde{A}^i$).

²⁷Caselli and Coleman (2006) estimate labor efficiency parameters A_u and A_s of the same production function using the skill premium, and find heterogeneity across countries.

²⁸A summary of the project is presented in Krueger, et al (2010). I also obtain data for individual countries from Blundell and Etheridge (2010), Fuchs-Schuendeln, et al. (2010), Jappelli and Pistaferri (2010), and Pijoan-Mas and Sanchez-Marcos (2010), which summarize macroeconomic facts in Britain, Germany, Italy, and Spain, respectively. From here on, I denote this series of papers as CSFM.

the model: the altruism factor β , weight on utility of leisure η , and the curvature of the utility of leisure γ . Since households live for two periods, I assume a model time period of 30 years. Thus, I find $\beta^{\frac{1}{30}}$ to match the annual interest rate of 4 percent. In order to jointly pin down the values of η and γ , average hours worked in the UK and the Frisch labor supply elasticity are used as targets. The OECD reports that the average hours worked in the UK is around 1,715 hours annually, or 4.70 hours a day. Letting time endowment be around 13 hours a day, this is equivalent to labor hours of 0.361. Moreover, the target value of the Frisch labor supply elasticity (γ) is 0.3 (Browning et al. (1999)).²⁹

C. Ability and Human Capital Production. I assume that ability across generations follows a first-order Markov process with mean normalized to one. In particular, the following AR(1) process is used:

$$\log z' = \rho_z \log z + \varepsilon, \quad \varepsilon \sim (0, \sigma_z^2),$$

which leaves two parameters, ρ_z (correlation of ability across generations) and σ_z^2 (variance of error term) to be calibrated, where I use Tauchen method with 5 grid points to discretize the process.

Probabilities of becoming a skilled or unskilled worker, $Q(s|z, \tilde{x})$ and $Q(u|z, \tilde{x})$, are specified as follows:

$$\begin{aligned} Q(s|z, \tilde{x}) &= \min\{\nu^i z \tilde{x}^{\xi^i}, 1\} \\ Q(u|z, \tilde{x}) &= 1 - Q(s|z, \tilde{x}). \end{aligned}$$

This functional form satisfies decreasing marginal returns in human capital investment with $\xi^i < 1$. Moreover, the returns to human capital investment are increasing in ability. Therefore, there are two parameters for each country to be calibrated: $\{\nu^{UK}, \nu^{CE}\}$, the technology of human capital production, and $\{\xi^{UK}, \xi^{CE}\}$, the returns to human capital investment. I normalize $\nu^{UK} = 1$ and find $\{\xi^{UK}, \xi^{CE}, \nu^{CE}\}$ within the model, leaving a total of 5 parameters including the ability parameters ρ_z and ε_z^2 .

These parameters affect the intergenerational persistence in schooling, percentage of college graduates, and percentage of GDP spent on education. In the UK, schooling persistence is 0.22. The OECD reports that the percentage of college graduates among the 25 – 64-year-old age group is 26 percent for the UK and about 20 percent in the CE. Moreover, the total percentages of GDP spent on tertiary education in 2000 are 0.78 percent and 1.05 percent in the UK and CE, from which 0.6 percent and 0.9 percent are public spending, and the rest, private.

One of the key aggregate outcomes that I would like to analyze in this paper is the skill

²⁹Since the model time period is around 30 years, households might not respond to wage rates as much as macro Frisch elasticities used in business cycle studies suggest. Therefore, I use the target Frisch elasticity to those estimated and commonly used in micro literature.

distribution in different countries. As shown in the summary statistics, the share of skilled population in the CE is only about 80 percent of that in the UK. With common ability and human capital production function parameters, such big differences in skill distribution cannot be matched. Since the education system and quality of countries can differ, I allow for heterogeneity in technology (ν) and returns to human capital investment (ξ) across countries. This makes it possible to match the education spending and skill distribution across countries, with which I can analyze the effects of different tax systems in both countries.

D. Labor Productivity Shocks. I assume that the i.i.d. productivity shock to labor income is drawn from a log-normal distribution:

$$\log \varepsilon \sim N(0, \sigma_\varepsilon^2).$$

The value of σ_ε^2 is found to match labor earnings Gini in the UK, which is reported to be 0.45 in 2000 from Blundell and Etheridge (2010).

E. Migration. Moving cost shocks have an exponential distribution (as in Armenter and Ortega (2009)) with skill-dependent scale parameters of $\{k_u, k_s\}$ and a minimum value of moving cost (location preference) $\{\underline{k}_u, \underline{k}_s\}$, i.e.,

$$f(h) = k_i e^{-k_i(h + \underline{k}_i)}, \quad i \in \{u, s\}.$$

Since this is a steady-state analysis of an open-economy with labor and capital mobility, *net* mobility is always zero (while *gross* mobility might not be). Therefore, I set the percentage of migration *stock* in the UK (from the CE) in its population as one of the data targets.

In order to match the percentage of college-educated migrants (positive selection is evident, as seen in Table 1), I assume heterogeneity in scale parameters of the exponential distribution across skill levels. Relevant targets are the population ratio between the two countries and the percentage of college-educated immigrants.

Table 2 summarizes the model parametrization.

3.4 Calibration Results

Values of the calibrated parameters and model fit are presented in Tables 3 and 4.

As emphasized before, there are two fundamental differences between the two countries: the efficiency of skilled and unskilled labor in production, and the human capital production technology. In the calibration exercise, I find that the UK has higher efficiency of skilled labor compared to unskilled labor in production, i.e.,

$$\frac{A_S^{UK}}{A_U^{UK}} > \frac{A_S^{CE}}{A_U^{CE}}.$$

Moreover, the sum of labor efficiencies in the CE ($A_u^{CE} + A_s^{CE}$) is 0.945, which is lower than normalized value of 1 in the UK.³⁰ The differences in labor efficiency parameters between the UK and CE are qualitatively similar to those found in Caselli and Coleman (2006). The calibrated parameters of the human capital production technology shows that the CE has higher technology (ν) and higher returns to human capital investment (ξ), conditional on ability of a parent.

These parameters (production and human capital technology) are found jointly to match the GDP per capita ratio and skill premia, skill distributions, and education spending in both economies. The UK has higher skill premium and higher percentage of skilled workers in general equilibrium, which is consistent with the higher relative efficiency of the skilled in production. Moreover, high technology of human capital production and returns to human capital investment are necessary to match the skill distribution in the CE, while having a low skill premium. The model is successful in matching targets along these dimensions.

Migration parameter choices also require some discussion. Since I conduct a steady-state analysis, *net* migration in both countries is always zero by construction. Therefore, in order to ensure a stationary distribution of population in both countries, households should migrate to and from both countries. To achieve this, I allow for the minimum value of the location preferences (including moving costs) to be negative, which implies that a household living in the UK might prefer living in the CE and vice versa. This allows households in the UK to migrate to the CE, for example, even though it is not in their best interest to do so for economic reasons. I use data on migration *stock* as a calibration target. In the *status quo* economy, migration stocks from the CE in the UK is only 1.1 percent of the total UK population.³¹ This leads to a large value for the scale of the distribution, implying a very strong preference for households to live in their birth country. The lower scale for the skilled compared to unskilled reflects the lower cost of migration for the skilled.³²

In the fully calibrated economy, government revenues collected from labor and capital income taxes amount to about 30 percent of GDP in the UK and CE. According to the OECD Tax Database, total tax revenues in the UK and CE (in 2000) are 37 percent and 40 percent respectively, among which 30 percent are collected as consumption taxes (general and specific). Since consumption, capital, and labor income taxes constitute three major sources of tax revenues, labor and capital tax revenue range between 26 and 28 percent.³³ Thus, the calibrated economy is within a reasonable range in terms of the magnitude of tax revenues relative to GDP. Moreover, more

³⁰The parameter values imply that the production function in Equation (20) is represented as

$$\begin{aligned} F^{UK}(K, U, S) &= K^\alpha (0.5762U^\rho + 0.4238S^\rho)^{\frac{1-\alpha}{\rho}}; \\ F^{CE}(K, U, S) &= 0.8764K^\alpha (0.6534U^\rho + 0.3466S^\rho)^{\frac{1-\alpha}{\rho}}, \end{aligned}$$

for the UK and CE, respectively. The overall productivity is lower in the CE (0.8764) and the unskilled efficiency in production, higher (0.6534), than in the UK.

³¹Total migration stock in the UK is about 11 percent of its population, with 3.5 percent coming from other EU countries. However, since I want to focus on the effect of different tax policies on migration and aggregate outcomes between the UK and the CE, 1.1 percent is the relevant data target for the purpose of this paper.

³²This is consistent with qualitative differences in estimates for moving costs in Armenter and Ortega (2009).

³³Specific tax categories include personal income tax, corporate income tax, social security contributions, payroll taxes, property taxes, and general and specific consumption taxes.

importantly, estimated elasticity of capital with respect to tax rate is about 3.8 percent, which is in the range of that observed in the data.

3.5 Computation of Nash Equilibrium

Before I analyze the results in detail, I briefly describe the quantitative procedures of solving for the Nash equilibrium.

In order to find a Nash equilibrium of the tax competition game, I generate a grid of the labor income tax parameters, a_0 and a_1 . Taking as given the tax system of country j ($\{a_0^j, a_1^j, \tau_k^j\}$), country i searches over the set of grids $\{a_0, a_1\}$ to find the tax system that maximizes the steady-state welfare of households, while collecting a fixed amount of tax revenue per capita.

As governments' budget constraints have to be satisfied period by period, I find capital income tax rate τ_k that balances country i 's budget, given the labor income tax code represented by $\{a_0, a_1\}$.³⁴ This procedure is repeated iteratively for countries i and j , until a fixed point is found. Given the high dimensionality of the choice variables, the uniqueness of the Nash equilibrium cannot be guaranteed. However, I searched over big domains of tax parameters and tried starting from various initial tax systems, and have not found multiple equilibria. I describe this procedure in more detail in Appendix C.

In the following sections, I present the quantitative results based on the calibrated parameters.

4 Results

To more intuitively understand the forces leading to the optimal taxation results, I first start by analyzing household behaviors. Then I let each government (UK and CE) vary its tax code (a_0, a_1 , and τ_k) one by one, and analyze its aggregate effects and welfare. This exercise provides an intuitive picture of what the best response of each country is, taking as given the *status quo* tax system of the other. After presenting the best responses, I discuss the Nash equilibrium tax system and its aggregate outcomes. Finally, by comparing the optimal taxation in the benchmark economy (*both* capital and labor mobility) to the economy with *only* capital mobility, I study how labor mobility affects the fiscal choices of governments.

4.1 Understanding Household Behavior

Governments in the economy maximize the steady state welfare of households. Therefore, understanding household behaviors is an important first step in understanding the optimal taxation results.

Among the most important components in the model are the human capital investment and the migration decisions of households. Since governments in both countries provide public education,

³⁴Notice that since this is a general equilibrium model, equilibrium allocations and prices are determined given the tax systems in *both* countries.

for households whose return to human capital investment is low, their optimal investment (x) in the model is zero. Given that marginal returns to human capital investment is increasing in ability, these are households with low ability levels.

The incentives to invest in human capital also differ across skill group and country of residence. Figure 3 shows the human capital investment decisions of households living in the UK and CE across skill groups, for the highest-ability parents as a function of asset level (under the *status quo* tax system). The skilled parents, whose labor income is higher, invest more in the human capital of the offspring than their unskilled counterparts do, since they have higher total wealth. Moreover, households living in the CE have less incentives to invest in human capital, since the skill premium is lower, the labor income tax rate (and progressivity) is higher, *and* the public education expenditure in the CE is higher.

To understand the migration decisions of households, in Figure 4, I plot the differences in the value of living in the CE and living in the UK, for households with different skill and ability levels, across assets. As is evident from the figure, the skilled prefer living in the UK, since the skill premium is higher *and* the labor income tax rate is lower than those in the CE. Moreover, parents whose children are of low ability prefer living in the CE (conditional on their own skill level), where the public education expenditure *and* the return to human capital investment are higher than those in the UK. However, the differences in the value of living in the UK and CE vanish as assets increase, since labor income becomes a smaller share of the total household wealth and there is a global financial market (the after-tax returns to capital are equalized across countries).

These household behaviors show that government policies, along with fundamentals in the economy, can have important implications for the aggregate outcomes, especially with international movement of labor.

4.2 From *Status Quo* to the Nash Equilibrium

In this subsection, I discuss the response of the UK (CE) government to the *status quo* tax system of the CE (UK). This analysis provides insight into the optimal choices of the governments.

Effects of Changes in the Tax Code. First, I consider the effects of changes in τ_k , a_0 , and a_1 of the UK, taking as given the CE's *status quo* tax system. Table 5 presents the effects of lowering the capital income tax rate τ_k and labor income tax rate a_0 (keeping progressivity constant) by 1 percent, and the effects of reforming the labor income tax code to a proportional tax.

As is evident in Table 5, lowering the capital income tax rate is the most effective tool for increasing capital. Capital increases by 3.8 percent in response to a 1 percent decrease in the capital income tax rate. On the other hand, changes in the labor income tax code increase average hours worked in the economy. In the current formulation of the tax code, the governments can take two routes for reforming the tax code: either lower the *average* labor income tax rate (through higher a_0) or lower the progressivity of the tax code (through lower a_1). The comparison of the last

two columns of Table 5 shows that lowering the progressivity of the labor income tax code leads to a higher increase in labor provided, as well as an increase in the number of skilled immigrants.

The last three rows in Table 5 present the consumption equivalent variations: the consumption increase necessary for households to be indifferent between living in the *status quo* economy or in the economy with the new tax regime. It is clear that the capital income tax reform performs the best in increasing the overall welfare of households; the consumption equivalent variations are the highest in this case. Another interesting aspect of the economy is that implementing a proportional labor income tax system results in a welfare loss: the insurance benefits from using a progressive labor income tax code outweigh its incentive costs. Even though the skilled households are in favor of the proportional labor income tax code (0.019), the unskilled, who comprise about 75 percent of the population in the UK, suffer welfare loss (-0.008). The heterogeneity in ability levels and idiosyncratic labor income risks cannot be insured in the market, and governments play important roles in providing insurance benefits against these risks. A *progressive* labor income tax code achieves this goal.

Unilateral Reform: Best Response to the *Status Quo* Tax System. The analysis in the previous section provides insight into what the UK(CE) government would do, if it reformed its tax system *unilaterally*, i.e., given the *status quo* tax system of the CE(UK), what is the best response of the UK(CE)? Under the unilateral reform, the UK sets its capital income tax rate at -35 percent (subsidized), average labor income tax rate at 53 percent, and progressivity at 0.25 (value of a_1). The changes to the aggregate outcomes in the UK compared to the *status quo* are presented in Table 6.

The dramatic decrease of the capital income tax rate in the UK (from 48 percent to -35 percent) leads to higher capital and output per capita. The return to capital decreases by 42 percent, but due to the capital income subsidy, the after-tax return to capital increases by 19 percent. Moreover, as higher capital increases the marginal product of labor, wages of both unskilled and skilled labor also increase by around 37 percent.

The results of the analogous exercise for the CE are presented in Table 7. The CE also lowers its capital income tax rate and increases progressivity, but the magnitudes are smaller. Since the *status quo* capital income tax rate in the UK (48 percent) is higher than that in the CE (28 percent), it attracts sufficient capital at a relatively higher capital income tax rate.

The presentations of the effects of changes in the tax code and the best responses to the *status quo* tax system lead us to analyze the Nash equilibrium results, which I proceed to do in the following section.

4.3 Nash Equilibrium of the Tax Competition Game

The Nash equilibrium of the tax competition game is

$$\begin{aligned}\bar{\tau}_y^{*UK}(y) &= 0.52, & a_1^{*UK} &= 0.28 & ; & \tau_k^{*UK} &= -0.32 \\ \bar{\tau}_y^{*CE}(y) &= 0.50, & a_1^{*CE} &= 0.11 & ; & \tau_k^{*CE} &= 0.06.\end{aligned}$$

The average labor income tax rates in the UK and CE are 52 percent and 50 percent, respectively. While the UK subsidizes its capital income at 32 percent, it uses a more progressive labor income tax code than the CE does. Figure 5 plots the average labor income tax rates for those with different income levels in the Nash equilibrium. Moreover, as a measure of progressivity, I also plot in Figure 6, progressivity wedges defined as

$$1 - \frac{1 - \tau(k \times 0.5)}{1 - \tau(0.5)} \text{ for } k = 2, 3, \dots, 5,$$

following Guvenen et al (2013). The interpretation is as follows: In the Nash equilibrium, a household living in the UK, whose labor earning is two times the average earning in the economy, earns 25 percent less than they would in a flat-tax system. An analogous worker earns 12 percent less, if he resides in the CE. In the *status quo*, the wedges are 8 and 10 percent respectively, in the UK and CE. Therefore, it is evident that the UK uses a much more progressive labor income tax code to collect tax revenues.

Before analyzing the aggregate effects of implementing the Nash equilibrium policies and the impact of competition between the two countries, several properties of the Nash equilibrium tax systems are worth discussion.

First, both countries use labor income tax as a dominant source of tax revenue. In the model, capital is more mobile than labor, as migration incurs utility costs. Therefore, both countries levy lower taxes on the mobile factor. Secondly, the UK subsidizes capital income. In the model economy, labor income risks cannot be insured in the market, i.e., financial markets are incomplete. From the government's point of view (which maximizes the steady-state welfare of households, using a utilitarian welfare function), the most efficient way of increasing societal welfare is to increase the lifetime utility of the consumption-poor, as they are the segment of society with the highest marginal utility of consumption. Thus, as shown in Davila et al. (2012), an important determinant of the optimal capital income tax rate is the wealth composition of the poor in the competitive equilibrium (without government policies). If the consumption of the poor is low since they are *relatively* more wealth-poor (but have an abundant labor endowment), then social planners can increase the welfare of the poor by increasing capital, since an increase in capital would result in higher wages. On the other hand, if the poor in the economy is *relatively* more labor income-poor (but have high asset positions), the welfare of the poor can be increased if the return to capital is higher – an argument for positive capital income tax rate. The UK has higher efficiency of using skilled labor and its inequality is higher. Therefore, the UK government benefits more from

increasing capital, which also drives up wages. This leads to the optimal capital income tax rate being relatively lower (negative – capital income is subsidized) than that in the CE, and the optimal labor income tax code, more progressive.

Aggregate Outcomes in the Nash Equilibrium. Table 8 presents the changes in the aggregate outcomes in the UK and CE (relative to the *status quo*) when both countries implement the Nash equilibrium tax systems.

In the Nash equilibrium, the UK lowers its capital income tax rate dramatically. As a consequence, output per capita increases in the UK by 21 percent, and capital per capita more than doubles. However, the CE, which under the *status quo* had higher capital per capita than the UK does not perform economically as well as the UK does in the Nash equilibrium. Its output and capital per capita decreases. However, the *lower* capital income tax rate in both countries, compared to the *status quo* leads to *higher* after-tax returns to capital. Therefore, even with lower average working hours, consumption per capita in both countries increases.

Another notable aspect of the economy is the lower number of skilled workforce in the Nash equilibrium. As the after-tax return to *physical* capital investment increases, the incentives to invest in *human* capital decreases. Moreover, the highly progressive labor income tax code, compared to the *status quo*, decreases the incentives for parents to invest in the human capital of their offspring. As a result, the intergenerational schooling persistence in the UK decreases. In the UK, the decrease in the human capital investments are more pronounced for the skilled, since they have higher asset income. Therefore, the resulting schooling persistence is lower in the UK. On the other hand, under the Nash equilibrium policies and with its (relatively more) generous public education system, in the CE, households' human capital investment nears zero. Thus, the relative importance of ability increases slightly, resulting in higher schooling persistence. The cross-sectional inequality in both countries increases, as measured by the income Gini coefficient, because the asset-rich households decrease their working hours.

While there are less number of skilled workforce globally, the percentage of skilled (out of total number of skilled households) living in the UK increases by about 5 percent in the Nash. This is despite highly progressive income tax code in the UK. As the UK subsidizes its capital income, its capital in the steady state is large, and this leads to higher wages. Therefore, even with high labor income tax rates, *after-tax* labor income is still higher in the UK, attracting more skilled labor under the Nash policies. It is worth emphasizing, therefore, the importance of incorporating mobility of *both* capital and labor in analyzing optimal taxation in open economies.

Overall, implementing the Nash equilibrium policies leads to a significant increase in lifetime welfare of households, as measured in consumption equivalent variation. While the welfare in the UK increases by around 13 percent, the welfare in the CE increases by around 10 percent. The welfare increase is derived from the higher consumption per capita *and* lower hours worked. The unskilled benefit more than the skilled do, by about twofold, in both countries, thanks to the use of (more) progressive labor income tax codes.

Effects of Competition. Given the best responses of the governments discussed in section 4.2, the model can be used to analyze the effects of competition on optimal taxation. Comparing the Nash equilibrium tax rates with the tax rates of the unilateral reforms, I find that the governments set *lower* capital income tax rates under the unilateral reform than they do in the Nash equilibrium.

When either country reforms its tax system *unilaterally*, they take the other country's *status quo* tax rates as given, which are 48 and 28 percent respectively for the UK and CE. In the Nash, the analogous rates are -32 and 6 percent. Therefore, with competition, the UK faces a lower capital income tax from the CE. Then, the benefit of lowering the capital income tax rate is higher in the unilateral reform, since the CE's capital income tax rate is high, i.e., there is more capital that can be taken advantage of. The same holds for the CE. Thus, both governments set *lower* capital income tax rates when they unilaterally reform their tax systems.

4.4 Effects of Labor Mobility on Optimal Taxation and Aggregate Outcomes

In this subsection, I study the effects of labor mobility on optimal taxation in the UK and CE.

For the analysis, I find the optimal tax code in an economy with *only* capital mobility. In the first subsection, I compare the optimal taxation under capital versus capital and labor mobility. I also discuss the aggregate outcomes under the two economies to analyze the macroeconomic effects of labor mobility.

Optimal Taxation *with* versus *without* Labor Mobility. Table 9 summarizes the optimal tax codes of the UK and CE in the economies under different mobility assumptions.

A noticeable finding is the *divergence* of the tax systems in the UK and CE. In an economy where only capital is mobile, the capital income is subsidized at around 11 percent in both countries. However, with labor mobility, while the UK lowers its capital income tax rate, the CE increases it. Such divergence of the tax system in an economy with labor mobility is driven from the productivity differences in the UK and CE. As emphasized before, in the calibrated economy, the UK has higher productivity than the CE does.³⁵ Thus, when labor is mobile, the UK attracts more capital *and* labor: The population ratio between the UK and CE (UK to CE) is greater than one. Therefore, the welfare maximizing level of capital in the UK is larger than that in the CE. Thus, in order to attract more capital, the UK lowers its capital income tax rate under labor mobility. However, for the CE, given the lower level of labor provided (small population), the reverse is true: it finds it optimal to tax capital income.³⁶

³⁵As specified in footnote 31, the overall productivity in the CE (0.8764) is lower than that in the UK (1).

³⁶Another way to understand the result is through a global financial market. In equilibrium, after-tax marginal product of capital are equalized across countries by no-arbitrage condition. Conditional on capital and capital income tax rates, the UK is more productive and bigger (more labor) than the CE, shifting up its marginal product of capital. To get to an equilibrium, the UK can either increase its capital income tax rate (which will lower capital) or increase capital. Since elasticity of capital with respect to capital income tax rate is greater than one in the model, subsidizing capital income, and thus increasing capital is a more effective way of achieving this goal.

Aggregate Outcomes *with* versus *without* Labor Mobility. In Table 10, I compare aggregate outcomes in the economy with only capital mobility and the one with both capital and labor mobility.

As countries open up to labor mobility, the UK, which is more productive, gains as output and capital per capita increase. While the output and capital per capita in the CE decreases, with more unskilled and skilled labor provided, consumption per capita increases. Moreover, given the higher relative efficiency of the skilled in the UK, more skilled workers live in the UK, while in the CE, more unskilled workers reside. Thus, there is a reallocation of labor across countries.

The analysis in this section shows that labor mobility has important implications for the optimal taxation of capital and labor. In the calibrated model, the UK lowers its capital income tax rate, while the CE lowers its labor income tax rate, compared to an economy with *only* capital mobility. In the aggregate, the UK, which is more productive and has higher relative efficiency of the skilled, grows in population size and enjoys higher output and capital per capita, when labor is mobile.

5 Conclusions

The recent trend of increased labor mobility has raised concerns about the possibility of international labor income tax competition among policy makers. In light of this trend, this paper asks how labor mobility affects the optimal choice of governments' tax policies in an international tax competition framework.

Based on a two-country, open-economy model, I find that factor mobility and strategic interaction between governments are important factors in determining the optimal tax systems. The application of the model to the United Kingdom and Continental European countries shows that countries set their capital income tax rates less aggressively in a competitive environment. Moreover, in the United Kingdom, the optimal taxation of capital income is lower under both capital and labor mobility, compared to an economy with only capital mobility, while the reverse is true in the Continental Europe. It is worth emphasizing the importance of modeling mobility of both factors in a coherent framework. This allows the economists to correctly weigh the tradeoffs governments face in using capital versus labor income taxes. Though some policy makers worry that international tax competition can be harmful, implementing the Nash equilibrium tax rates in both countries increases steady state welfare by more than 10 percent of consumption in the *status quo* economy.

The Nash equilibrium policies that I find in this paper are distinct from the *status quo* policies (data). The policies presented here are the long-run tax systems that would arise, given the increased labor mobility in recent decades and competition between governments. The results are specific to the government's welfare function. Here, governments maximize the steady state welfare of residents, with a utilitarian social welfare function. Accounting for the welfare during a transition to the new steady state and/or assigning differential weights to residents and migrants will affect the results in this paper. However, this paper could be a starting point for the optimal taxation

analyses in an open economy.

An interesting avenue for future research is to endogenize the choice of public education expenditures (or more broadly, welfare programs) in governments' problems. Since governments' public education policies affect the migration decisions of skilled and unskilled households differentially, education policies might be used to attract migrants selectively.³⁷ Moreover, the interaction between using a progressive labor income tax code and a generous public education policy can be analyzed in an international tax competition framework.

The model developed in this paper is useful beyond the analysis of the United Kingdom and Continental Europe. An important policy dimension I (can) abstract from in this paper is the immigration policy. In the United States and many other countries, immigration reform is at the forefront of policy discussions. Kennan (2013) is one of the recent papers that studies the effects of immigration policies. This model can complement the literature by incorporating how tax systems influence migration decisions of households, and thus its implications for optimal immigration and tax policies. Studying immigration and taxation policies in a unified framework would lead to a more comprehensive policy analysis in a globalized world that we live in. I leave these questions for future research.

³⁷Anderson (2005) theoretically investigates the link between taxation and educational policies in presence of migration.

6 Tables and Figures

Table 1: Summary Statistics in the United Kingdom and Continental Europe

	United Kingdom	Continental Europe
GDP per capita ^a	\$25,255	\$25,123
Skill premium ^a	1.62	1.44
Intergenerational persistence in schooling ^b	0.22	0.23
Gini coefficient of labor earning ^a	0.45	0.36
% college graduates ^c	25.7 %	19.6%
Tertiary education spending (% GDP) ^c	0.78%	1.05%
Public spending	0.58%	0.89%
Private spending	0.20%	0.16%
Average hours worked ^c	0.36	0.34
% of immigrants among pop. ^b	1.10%	0.52%
% college graduates among immigrants ^d	37.70%	36.25%

^a. Cross Sectional Facts for Macroeconomists (2011)

^b. Causa and Joahnsson (2009)

^c. OECD

^d. OECD and World Bank

Note: All statistics are data from 2000.

Table 2: Calibration Targets

Parameter	Description	Target	Value
A_u^{UK}	Unskilled efficiency – UK	Skill premium – UK	1.62
A_u^{CE}	Unskilled efficiency – CE	Skill premium – CE	1.44
A_s^{CE}	Skilled efficiency – CE	GDP per capita ratio	1.00
α^*	Capital share	-	0.33
$\frac{1}{1-\rho}^*$	Elasticity of Substitution	-	1.4
δ	Depreciation rate	Capital-output ratio – UK	3.0
σ^*	Risk aversion	-	2
η	Weight in disutility of labor	Average hours worked – UK	0.36
γ	Curvature of leisure	Frisch elasticity	0.3
$\beta^{\frac{1}{30}}$	Discount (altruism) factor	Annual bond yields	4%
ρ_z	Persistence in ability	Intergen. sch. pers. – UK	0.22
σ_z^2	Variance in ability	Educ. spending – UK	0.78%
ν^{CE}	HC technology	Educ. spending – CE	1.05%
ξ^{UK}	Returns to HC inv. – UK	% college grads – UK	26%
ξ^{CE}	Returns to HC inv. – CE	% college grads – CE	20%
σ_ε^2	Var. of iid. shock	Labor earnings Gini – UK	0.45
$\underline{h}_U$	Min. utility cost of moving – unskilled	Pop. ratio – UK to CE	0.91
$\underline{h}_S$	Min. utility cost of moving – skilled	% imm. among pop. – UK	1.1%
h_U	Scale of cost distribution	% skilled among imm. – UK	38%
h_S	Scale of cost distribution	% skilled among imm. – CE	36%

* These parameters are chosen outside the model, and take standard values used in macroeconomics literature.

Table 3: Calibrated Parameters

Parameter	Description	Value
A_u^{UK}	Unskilled efficiency – UK	0.577
A_u^{CE}	Unskilled efficiency – CE	0.618
A_s^{UK}	Skilled efficiency – UK	0.423
A_s^{CE}	Skilled efficiency – CE	0.329
δ	Capital depreciation rate	0.049
ρ_z	Persistence in ability	0.362
σ_z^2	Variance in ability	0.570
ξ^{UK}	Returns to HC investment – UK	0.197
ξ^{CE}	Returns to HC investment – CE	0.253
ν^{UK}	Skill production technology – UK	1.000
ν^{CE}	Skill production technology – CE	1.145
σ_ε^2	Variance in labor productivity shock	1.076
η	Weight in disutility of labor	777
γ	Frisch elasticity	0.3
β	Discount (altruism) factor	0.948
$\underline{h}_U$	Minimum utility cost of moving – unskilled	89
$\underline{h}_S$	Minimum utility cost of moving – skilled	59
h_U	Scale of moving cost distribution – unskilled	9800
h_S	Scale of moving cost distribution – skilled	3200

Table 4: Model Fit

Moments	Data	Model
Skill premium – UK	1.62	1.62
Skill premium – CE	1.44	1.44
GDP per capita ratio	1.01	0.96
Capital-output ratio	0.1	0.1
Annual bond yields	1.04	1.04
Intergenerational persistence in schooling – UK	0.22	0.20
Gini coefficient of labor earning – UK	0.45	0.45
% college graduates – UK	25.7%	25.2%
% college graduates – CE	19.6%	20.1%
Tertiary education spending (% GDP) – UK	0.78%	0.74%
Tertiary education spending (% GDP) – CE	1.05%	1.05%
Average hours worked – UK	0.36	0.35
Population ratio – UK to CE	0.91	0.97
% of immigrants among Pop. – UK	1.1%	1.1%
% college graduates among immigrants – UK	38%	34%
% college graduates among immigrants – CE	36%	41%

Table 5: Effects of Changes in the Tax Code – United Kingdom

Variable	$\tau_k^{UK} \downarrow$	$a_0^{UK}(y) \uparrow$	$a_1^{UK}(y) \downarrow$
Capital	0.038	0.006	0.015
Hours worked	0.000	0.002	0.005
Skilled immigrants	-0.001	0.000	0.004
Consumption equivalent variation	0.004	0.001	-0.002
Unskilled	0.003	0.000	-0.008
Skilled	0.007	0.004	0.019

Note: Starting from the *status quo* tax system in the United Kingdom, I vary each component in the tax system (capital income tax rate, average labor income tax rate, and progressivity of the labor income tax code) one by one. Since labor income tax function is

$$\tau(y; \bar{y}) = 1 - a_0 \left(\frac{y}{\bar{y}} \right)^{-a_1},$$

increasing a_0 is equivalent to lowering the average labor income tax rate, while decreasing a_1 represents a less progressive labor income tax code. All variables represent the changes of the aggregate outcomes from the *status quo* tax system in the United Kingdom, taking as given the *status quo* tax system in the Continental Europe.

Table 6: Unilateral Reform of the United Kingdom and Aggregate Outcomes

		UK		CE
		<i>Status Quo</i>	Unilateral	
Tax code	Capital income tax	0.48	-0.35	0.28
	Average labor income tax	0.24	0.53	0.31
	Progressivity	0.07	0.25	0.10
Aggregate outcome (UK)	Output per capita			0.27
	Capital per capita			1.42
	Average hours worked			-0.08
	Return to capital			-0.42
	After-tax return to capital			0.19
	Wages, unskilled			0.37
	Wages, skilled			0.38

Note: Aggregate variables are changes from the *status quo* tax system.

Table 7: Unilateral Reform of Continental Europe and Aggregate Outcomes

		UK	CE	
			<i>Status Quo</i>	Unilateral
Tax code	Capital income tax	0.48	0.28	-0.11
	Average labor income tax	0.24	0.31	0.44
	Progressivity	0.07	0.10	0.28
Aggregate outcome (CE)	Output per capita			0.08
	Capital per capita			0.35
	Average hours worked			-0.04
	Return to capital			-0.21
	After-tax return to capital			0.12
	Wages, unskilled			0.12
	Wages, skilled			0.12

Note: Aggregate variables are changes from the *status quo* tax system.

Table 8: Aggregate Outcomes in the Nash Equilibrium

Variable	Nash Equilibrium	
	United Kingdom	Continental Europe
Output per capita	0.21	-0.11
Capital per capita	1.18	-0.17
Average hours worked	-0.12	-0.13
Consumption per capita	0.04	0.04
Return to capital	-0.40	-0.02
After-tax return to capital	0.21	0.21
Percent skilled households	-0.02	-0.01
Labor income Gini coefficient	0.04	0.06
Schooling persistence	-0.14	0.01
Population	0.04	-0.04
Skilled immigrants	-0.03	-0.03
Consumption equivalent variation	0.13	0.10
Unskilled	0.14	0.11
Skilled	0.07	0.06

Note: All variables represent changes from the *status quo* tax system.

Table 9: Effects of Labor Mobility on Optimal Taxation

Optimal Tax Code		Capital Mobility	Capital & Labor
Capital income tax rate	UK	-0.12	-0.32
	CE	-0.11	0.06
Average labor income tax rate	UK	0.49	0.52
	CE	0.51	0.50
Progressivity	UK	0.25	0.28
	CE	0.25	0.11

Note: The tax codes are based on the optimal taxation in an economy with *only* capital mobility, and in an economy with *both* capital and labor mobility.

Table 10: Effects of Labor Mobility on Aggregate Outcomes

Variable	Nash Equilibrium	
	United Kingdom	Continental Europe
Output per capita	0.079	-0.074
Capital per capita	0.268	-0.219
Consumption per capita	-0.010	0.057
Unskilled labor	-0.001	0.002
Skilled labor	0.002	0.005
Percent skilled households	0.001	-0.002
Population	0.014	-0.014

Note: All variables represent changes from the optimal tax system with *only* capital mobility.

Figure 1: Timing of the Model

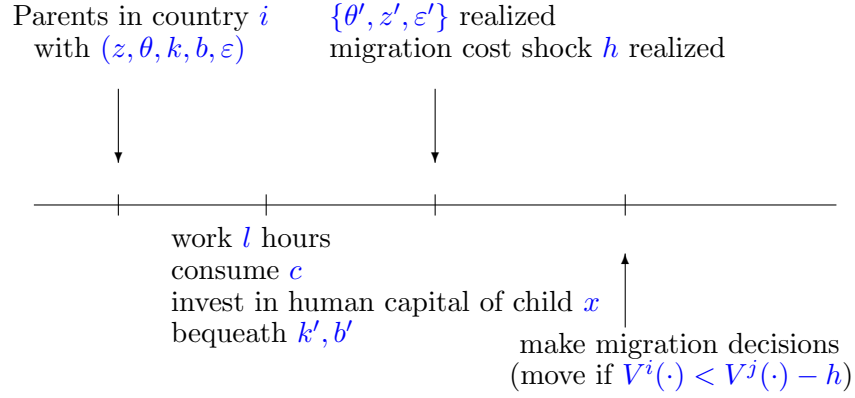
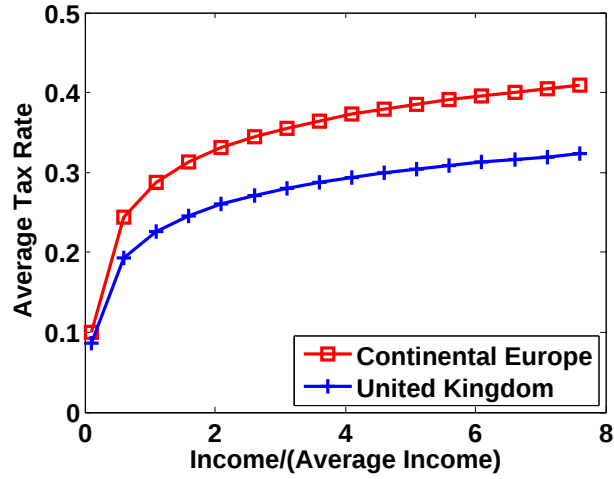
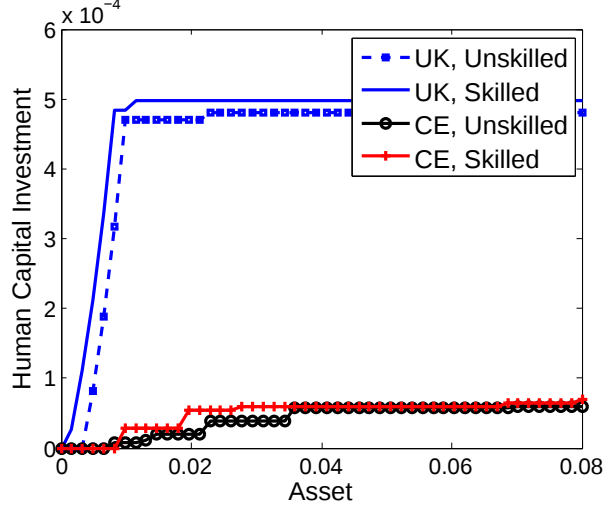


Figure 2: Average Labor Income Tax Rates in the Continental Europe and United Kingdom



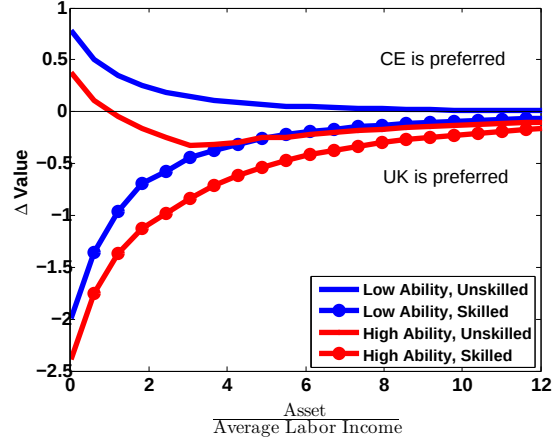
Note: The United Kingdom has a less progressive labor income tax code, with a lower average labor income tax rate, when compared to the Continental Europe.

Figure 3: Human Capital Investment Decisions of Households



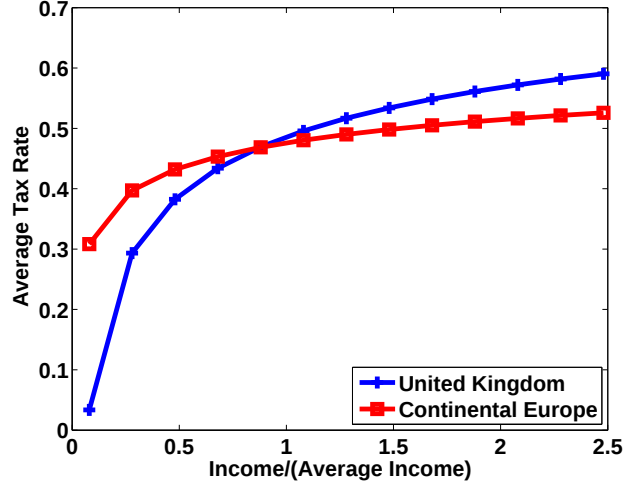
Note: Households living in the United Kingdom have higher incentives to invest in the human capital of their offspring conditional on skill level, thanks to the country's high skill premium and low labor income tax rate. Moreover, public education spending in the United Kingdom is lower, leaving more room for investment in children. On the other hand, investment by households in the Continental Europe is lower, since public education expenditures are high and the market incentives are lower (low skill premium and high labor income tax rates). The skilled parents invest more (conditional on assets) than the unskilled parents, since they have higher labor income.

Figure 4: Differences in the Value of Living in the United Kingdom versus Continental Europe



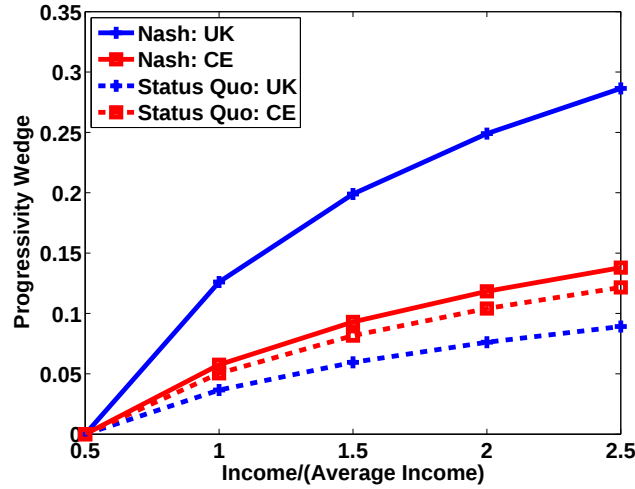
Note: The y -axis represents the differences in the value of living in the Continental Europe and living in the United Kingdom. A positive value implies that a household of a given characteristic prefers living in the Continental Europe. Overall, the skilled labor force prefers the United Kingdom, while households whose offspring is of low ability prefer living in the Continental Europe. The differences between living in the United Kingdom and Continental Europe vanish as assets increase.

Figure 5: Average Labor Income Tax Rates in the Nash Equilibrium



Note: In the Nash equilibrium, the United Kingdom uses a more progressive labor income tax code than the Continental Europe does.

Figure 6: Progressivity Wedge in the *Status Quo* and in the Nash Equilibrium



Note: Following Guvenen et al. (2013), progressivity wedge is defined as $1 - \frac{1 - \tau(k \times 0.5)}{1 - \tau(0.5)}$ for $k = 2, 3, \dots, 5$. The interpretation is as follows: In the Nash equilibrium, a household living in the United Kingdom, whose labor earning is two times the average earning in the economy, earns 25 percent less than in a flat-tax system. An analogous worker earns 12 percent less, if he resides in the Continental Europe. In the *status quo*, the wedges are 8 and 10 percent respectively, in the United Kingdom and Continental Europe.

References

- [1] Aghion, P., Boustan, L., Hoxby, C. and Vandenbussche, J., 2009, “The Causal Impact of Education on Economic Growth: Evidence from U.S.,” *Working Paper*.
- [2] Altonji, J. and Card, D., 1991, “The Effects of Immigration on the Labor Market Outcomes of Less-Skilled Natives,” In John Abowd and Richard B. Freeman, editors, *Immigration, Trade and Labor* Chicago: University of Chicago Press.
- [3] Altshuler, R., Grubert, H., and Newlon, T. Scott, 1998, “Has U.S. Investment Abroad Become More Sensitive to Tax Rates?,” *NBER Working Paper 6383*.
- [4] Anderson, T.M., 2005, “Migration, Taxation, and Educational Incentives,” *Economics Letters*, 87: 399-405.
- [5] Armenter, R. and Ortega, F., 2010, “Credible Redistributive Policies and Migration across U.S. States,” *Review of Economic Dynamics*, 13(2), 403-423.
- [6] Auerbach, A. and Oreopoulos, P., 1999, “Analyzing the Fiscal Impact of U.S. Immigration,” *American Economic Review Papers and Proceedings*, 89, 176-180.
- [7] Becker, G. and Tomes, N., 1979, “An Equilibrium Theory of the Distribution of Income and Intergenerational Mobility,” *Journal of Political Economy*, 87, 1153-1189.
- [8] Bell, B.D., 1997, “The Performance of Immigrants in the United Kingdom: Evidence from the GHS,” *The Economic Journal*, 107(441), 333-344.
- [9] Benabou, R., 2002, “Tax and Education Policy in a Heterogeneous-Agent Economy: What Levels of Redistribution Maximize Growth and Efficiency?,” *Econometrica*, 70(2), 481-517.
- [10] Benhabib, J. and Jovanovic, B., 2010, “Optimal Migration: A World Perspective,” *forthcoming*.
- [11] Bhagwati, J.N. and Hamada, K., 1982, “Tax Policy in the Presence of Emigration,” *Journal of Public Economics*, 18, 291-317.
- [12] Blundell, R. and Etheridge, B., 2010, “Consumption, Income, and Earnings Inequality in Britain,” *Review of Economic Dynamics*, 13(1) 76-102.
- [13] Borjas, G.J., 1987, “Self-Selection and the Earnings of Immigrants,” *American Economic Review*, 77 531-553.
- [14] Borjas, G.J. and Friedberg, R.M., 2009, “Recent Trends in the Earnings of New Immigrants to the United States,” *NBER Working Paper 15406*.

- [15] Brewer, M., Saez, E., and Shephard, A., 2010, “Means Testing and Tax Rates on Earnings,” *The Mirrlees Review: Reforming the Tax System for the 21st Century*, Oxford University Press.
- [16] Browning, M., Hansen, L.P., and Heckman, J.J., 1999, “Micro Data and General Equilibrium Models,” in J.B. Taylor and M. Woodford, eds, *Handbook of Macroeconomics*, 17,18.
- [17] Carey, D. and Tchilinguirian, H., 2000, “Average Effective Tax Rates on Capital, Labour and Consumption,” *OECD Working Papers* No. 258.
- [18] Caselli, F. and Coleman II, W.J., 2006, “The World Technology Frontier,” *The American Economic Review*, 96, 3, 499-522.
- [19] Causa, O. and Johansson, A., 2009, “Intergenerational Social Mobility,” *OECD Economics Department Working Papers*, No. 707, OECD Publishing.
- [20] Chari, V.V. and Kehoe, P.J., 1990, “International Coordination of Fiscal Policy in Limiting Economies,” *Journal of Political Economy*, 98, 617-636.
- [21] Cobb-Clark, D.A. and Hildebrand, V., 2006, “The Wealth and Asset holdings of U.S.-Born and Foreign-Born Households: Evidence from SIPP Data,” *Review of Income and Wealth*, 52, 17-42.
- [22] Conesa, J. C., Kitao, S., and Krueger, D., 2009, “Taxing Capital? Not a Bad Idea after All!,” *American Economic Review*, 99(1), 2548.
- [23] Conesa, J.C., Krueger, D., 2005, “On the Optimal Progressivity of the Income Tax Code,” *Journal of Monetary Economics*, 53(7), 1425-1450.
- [24] Davila, J., Hong, J.H., Krusell, P., and Rios-Rull, J.-V., 2012, “Constrained Efficiency in the Neoclassical Growth Model with Uninsurable Idiosyncratic Shocks,” *Econometrica*, 80, 2431-2467.
- [25] Devereux, M.P., Lockwood, B., and Redoano, M., 2008, “Do Countries Compete over Corporate Tax Rates?,” 92, 1210-1235.
- [26] Docquier, F. and Marfouk, A., 2005, “International Migration by Education Attainment, 1990-2000,” *World Bank Policy Research Working Paper*.
- [27] Erosa, A. and Koreshkova, T., 2007, “Progressive Taxation in a Dynastic Model of Human Capital,” *Journal of Monetary Economics*, 54, 667-685.
- [28] Erosa, A., Koreshkova, T., and Restuccia, D., 2010, “How Important is Human Capital? A Quantitative Theory Assessment of World Income Inequality,” *Review of Economic Studies*, 77, 1421-1449.

- [29] Fuchs-Schuendeln, N., and Krueger, D., and Sommer, M., 2010, "Inequality Trends for Germany in the Last Two Decades: A Tale of Two Countries," *Review of Economic Dynamics*, 13(1), 103-132.
- [30] Galor, O., 1992, "The Choice of Factor Mobility in a Dynamic World," *Journal of Population Economics*, 5, 135-144.
- [31] Gordon, R.H., 1986, "Taxation and Investment and Savings in a World Economy," *The American Economic Review*, 76(5), 1086-1102.
- [32] Gorter, J. and Parikh, A., 2000, "How Mobile is Capital Within the EU?," *CPB Research Memorandum*, No. 172, The Hague
- [33] Grogger, J. and Hanson, G.H., 2011, "Income Maximization and the Selection and Sorting of International Migrants," *Journal of Development Economics*, 95, 42-57.
- [34] Gross, T., 2012, "Dynamic Optimal Taxation in Open Economics," *Working Paper*.
- [35] Gross, T., 2013, "Dynamic Optimal Taxation and Capital Tax Competition," *Working Paper*.
- [36] Guvenen, F., Kuruscu, B., and Ozkan, S., 2013, "Taxation of Human Capital and Wage Inequality: A Cross-Country Analysis," *Review of Economic Studies*, forthcoming.
- [37] Ha, J. and Sibert, A., 1997, "Strategic Capital Taxation in Large Open Economies with Mobile Capital," *International Tax and Public Finance*, 4, 243-262.
- [38] Hanson, G.H., 2009, "The Economic Consequences of International Migration," *Annual Review of Economics*, 1, 179-208.
- [39] Heathcote, J., Storesletten, K., and Violante, G.L., 2012, "Consumption and Labor Supply with Partial Insurance: An Analytical Framework," *Working Paper*.
- [40] Hendricks, L., 2001, "How Do Taxes Affect Human Capital? The Role of Intergenerational Mobility," *Review of Economic Dynamics*, 4, 695-735.
- [41] Hendricks, L., 2002, "How Important is Human Capital for Development? Evidence from Immigrant Earnings," *American Economic Review*, 92, 198-219.
- [42] Hines, J.R., 1996, "Altered States: Taxes and the Location of FDI in America," *American Economic Review*, 86, 1076-1094.
- [43] Hines, J.R., 1999, "Lessons from Behavioral Responses to International Taxation," *National Tax Journal*, 52, 305-322.
- [44] Hines, J.R. and Rice, E.M., 1994, "Fiscal Paradise: Foreign Tax Havens and American Business," *Quarterly Journal of Economics*, 109, 149-182.

- [45] Holter, Hans, 2011, "Accounting for Cross-Country Differences in Intergenerational Earnings Persistence: The Impact of Taxation and Public Education Expenditure," *Working Paper*.
- [46] Jappelli, T. and Pistaferri, L., 2010, "Does Consumption Inequality Track Income in Italy?" *Review of Economic Dynamics*, 13(1), 133-153.
- [47] Judd, K.L., 1985, "Redistributive Taxation in a Simple Perfect Foresight Model," *Journal of Public Economics*, 28(1), 59-83.
- [48] Kanbur, R. and Keen, M., 1993, "Jeux Sans Frontières: Tax Competition and Tax Coordination When Countries Differ in Size," *The American Economic Review*, 83(4), 877-892.
- [49] Katz, L.F. and Murphy, K.M., 1992, "Changes in Relative Wages, 1963-1987: Supply and Demand Factors," *Quarterly Journal of Economics*, 107(1), 35-78.
- [50] Kennan, J., 2013, "Open Borders," *Review of Economic Dynamics*, *forthcoming*.
- [51] Klein, P. Quadrini, V., and Rios-Rull, J-V., 2005, "Optimal Time-Consistent Taxation with International Mobility of Capital," *B.E. Journals - Advanced in Macroeconomics*, 5.
- [52] Klein, P. and Ventura, G.J., 2007, "TFP Differences and the Aggregate Effects of Labor Mobility in the Long Run," *The B.E. Journal of Macroeconomics*, 7.
- [53] Klein, P. and Ventura, G.J., 2009, "Productivity Differences and the Dynamic Effects of Labor Movements," *Journal of Monetary Economics*, 56, 1059-1073.
- [54] Kleven, H.J., Landais, C., and Saez, E., 2013, "Taxation and International Mobility of Superstars: Evidence from the European Football Market," *American Economic Review*, 103(5), 1892-1924.
- [55] Kleven, H.J., Landais, C., Saez, E., and Schultz, E., 2013, "Migration and Wage Effects of Taxing Top Earners: Evidence from the Foreigners' Tax Scheme in Denmark," *Quarterly Journal of Economics*, *forthcoming*.
- [56] Krueger, D., Perri, F., Pistaferri, L. and Violante, G., 2010, "Cross Sectional Facts for Macroeconomists," *Review of Economic Dynamics*, 13(1), 1-14.
- [57] Pijoan-Mas, J. and Sanchez-Marcos, V., 2010, "Spain is Different: Falling Trends of Inequality," *Review of Economic Dynamics*, 13(1), 154-178.
- [58] Krusell, P., Ohanian, L.E., Rios-Rull, J-V., and Violante, G.L., 2000, "Capital-Skill Complementarity and Inequality: Macroeconomic Analysis," *Econometrica*, 68, 1029-1053.
- [59] Mendoza, E.G., Razin, A. and Tesar, L.L., 1994, "Effective Tax Rates in Macroeconomic Cross-Country Estimates of Tax Rates on Factor Incomes and Consumption," *Journal of Monetary Economics*, 34(3), 297-323.

- [60] Mendoza, E.G. and Tesar, L.L, 1998, "The International Ramifications of Tax Reforms: Supply-Side Economics in a Global Economy," *American Economic Review*, 88, 226-245.
- [61] Mendoza, E.G. and Tesar, L.L, 2005, "Why Hasn't Tax Competition Triggered a Race to the Bottom? Some Quantitative Lessons from the EU," *Journal of Monetary Economics*, 52, 163-204.
- [62] Mirrlees, J.A., 1982, "Migration and Optimal Income Taxes," *Journal of Public Economics*, 18, 319-341.
- [63] OECD "Special Feature: Trends in Personal Income Tax and Employee Social Security Contribution Schedules," Taxing Wages 2011, OECD 2012
- [64] Ohanian, L., Raffo, A., and Rogerson, R., 2008, "Long-term Changes in Labor Supply and Taxes: Evidence from OECD Countries 1956-2004," *Journal of Monetary Economics*, 55(8), 1353-1362.
- [65] Razin, A. and Sadka, E., 2011, "Tax Competition and Migration: The Race-to-the-Bottom Hypothesis Revisited," *NBER Working Paper 16670*.
- [66] Razin, A. and Sadka, E., 2013, "Migration and Tax Competition within a Union," *NBER Working Paper 19282*.
- [67] Razin, A. and Sadka, E., 2013, "Migration into the Welfare State: Tax and Migration Competition," *NBER Working Paper 19346*.
- [68] Saez, E. and Veall, M.R., 2005, "The Evolution of High Incomes in Northern America: Lessons from Canadian Evidence," *American Economic Review*, 95, 831-849.
- [69] Saint-Paul, G., 2004, "The Brain Drain: Some Evidence from European Expatriates in the United States," *IZA DP No. 1310*.
- [70] Shamsuddin, A.F.M., and DeVoretz, D.J., 2005, "Wealth Accumulation of Canadian and Foreign-Born Households in Canada," *Review of Income and Wealth*, 44, 515-533.
- [71] Storesletten, K., 2000, "Sustaining Fiscal Policy through Immigration," *Journal of Political Economy*, 108, 300-323.
- [72] Tauchen, G., 1986, "Finite State Markov-Chain Approximation to Univariate and Vector Autoregressions," *Economics Letters*, 20, 177-181.
- [73] Tiebout, C., 1956, "A Pure Theory of Local Expenditures," *Journal of Political Economy*, 64(5), 416-424.
- [74] United Nations, 2002, International Migration Report 2002, New York: United Nations.

- [75] Wildasin, D.E., 1988, "Nash Equilibria in Models of Fiscal Competition," *Journal of Public Economics*, 35, 229-240.
- [76] Wilson, J.D., 1999, "Theories of Tax Competition," *National Tax Journal*, 52(2), 269-304.

A Long-Term Changes in Tax Rates

Since the analysis conducted in the paper is a steady-state analysis, the aggregate statistics in 2000 might be the outcome of government policies in previous years. In this section, I document long-term changes in tax rates in the UK and CE presented in Figures in Mendoza and Tesar (2005) and an OECD report (2012).³⁸

There is a consistent trend of a higher capital income tax rate (Figure 7) and lower labor income tax rate (Figure 8) in the United Kingdom compared to France, Italy, and Germany. Moreover, top combined statutory personal income tax rates (an indication of the degree of progressiveness in labor income tax code) shows similar patterns in 1980s as it does in 2000 across countries (Figure 9).

Figure 7: Capital Income Tax Rates in Europe

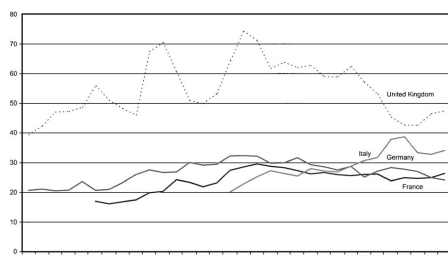


Fig. 1. Capital income tax rates in France, Germany, Italy and the UK: 1965-1996.

Figure 8: Labor Income Tax Rates in Europe

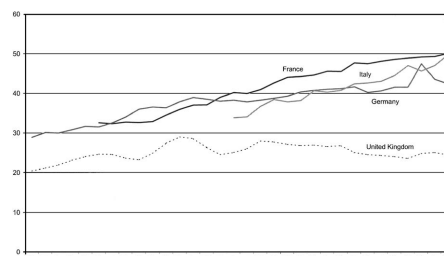
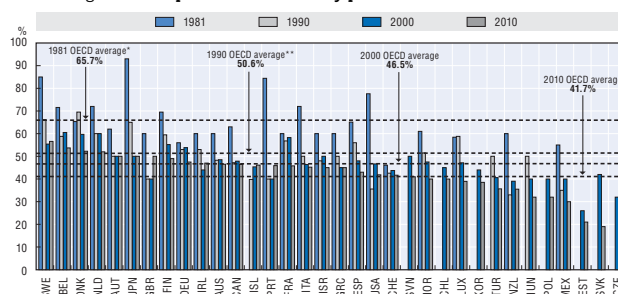


Fig. 2. Labor income tax rates in France, Germany, Italy and the UK: 1965-1996.

Figure 9: Trends in Top Labor Income Tax Rates in OECD Countries

Figure S.2. **Top combined statutory personal income tax rate**^{1, 2}



1. The sum of the central and sub-central top rates in PIT rate schedule, inclusive of surtaxes and adjusted for the deductibility of sub-central or other income taxes from the central tax base where applicable.
2. Countries are ranked by decreasing top statutory rates in 2010.

* 24-country average. The top rate is not applicable in the Czech Republic, Estonia, Hungary, Poland, the Slovak Republic, Slovenia, and not available for Chile, Iceland, Korea and Turkey.

** 27-country average. The top rate is not applicable in the Czech Republic, Estonia, Poland, the Slovak Republic, Slovenia, and not available for Chile and Korea.

Source: OECD Tax Database Tables L.1, L.2 and L.3 (www.oecd.org/ctp/taxdatabase/).

³⁸Figure 7 and 8 are from Mendoza and Tesar (2005), and Figure 9 from OECD.

B Summary Statistics of Continental European Countries

In the quantitative exercises, I analyze the tax competition between the UK and Continental European countries comprising France, Italy, Germany, and Spain. These are the countries in the European Union with *comparable* GDP per capita so that I could focus more on the economic incentives for households to move between the two regions. Moreover, the selected four countries have relatively higher labor (more progressive) income tax rates, and lower capital income tax rates than the UK. In getting the composite measures of macroeconomic outcomes and tax policies in the CE, I use weighted averages of these countries, where weights are obtained from the GDP and population of individual countries.

Aggregate Statistics Table 11 presents the summary statistics for the four Continental European countries that I analyze in the main part of the paper. Most of data are from IMF, OECD, and a series of papers under the project Cross Sectional Facts for Economists published in 2011.³⁹ The intergenerational persistence in schooling measures are taken from Causa and Johansson (2009) who use 2005 OECD data to obtain a percentage increase in probability of a child going to college when his father is a college graduate rather than upper-secondary educated.

Table 11: Summary Statistics of Continental European Countries

	France	Germany	Italy	Spain
GDP per capita ^a	\$25,972	\$26,090	\$24,669	\$22,359
Skill Premium ^b	-	1.38	1.51	1.48
Intergen. Schooling Persistence ^c	0.18	-	0.30	0.21
Gini of Labor Earning ^b	-	0.35	0.34	0.40
% College Graduates ^d	22 %	24%	9 %	22.6%
Tertiary Educ. Exp.(% GDP) ^d	1.32%	1.08%	0.83%	0.89%
Public Spending	1.13%	0.94%	0.70%	0.72%
Private Spending	0.18%	0.15%	0.13%	0.17%
Average Hours Worked ^d	0.333	0.307	0.388	0.363
Relative Weights	0.25	0.35	0.24	0.16

^a IMF

^b Cross Sectional Facts for Economists (2011)

^c Causa and Johansson (2009)

^d OECD

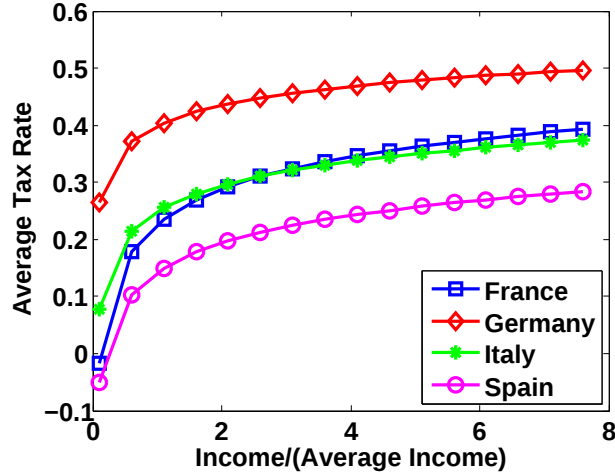
Labor Income Taxation Figure 10 plot the labor income tax functions

$$\tau(y) = 1 - a_0 \left(\frac{y}{\bar{y}} \right)^{-a_1}$$

³⁹Summary of the project is presented in Krueger, et al (2010). Moreover, I obtain data for individual countries from Blundell and Etheridge (2010), Fuchs-Schuendeln, et al. (2010), Jappelli and Pistaferri (2010), and Pijoan-Mas and Sanchez-Marcos (2010) which summarize macroeconomic facts in Britain, Germany, Italy, and Spain, respectively.

of the individual Continental European countries which are imputed using top marginal income tax rates and thresholds at multiples of average labor earnings ($\bar{y}$), following the procedure described in Guvenen et al (2013). These countries have progressive labor income tax schedules with Germany having the highest labor income tax rates and France, the most progressive.

Figure 10: Average Labor Income Tax Rates in Continental European countries



Capital Income Taxation In Table 12, capital income tax rates in individual Continental European countries are reported. There are several ways of calculating capital income tax rates. Since different capital incomes are taxed at different rates, it is difficult to find a single measure of capital income tax rates. Here, I use tax rates reported in Carey and Tchilinguirian (2000) who apply the methodology presented in Mendoza et al. (1994) to find average effective tax rates between the years of 1991 and 1997.

Mendoza et al. calculates *effective* tax rates by dividing sum of corporate income and personal capital income taxes by net operating surplus.

Table 12: Capital Income Tax Rates in Continental European Countries

Country	Capital Income Tax Rate
France	26.8
Germany	25.1
Italy	33.1
Spain	21.5

C Computation of the Nash Equilibrium

I describe the computation procedure of finding the Nash equilibrium tax systems. The governments in this model maximize the steady-state welfare of households by choosing labor income tax function parameters, a_0 and a_1 , and a capital income tax rate τ_k . Let $a_0 \in \{a_{01}, \dots, a_{0m}\}$ and

$a_1 \in \{a_{11}, \dots, a_{1n}\}$. Since I need to find the best responses taking as given the other country's tax rates, I iteratively find the tax parameters that maximize steady-state welfare of households in each country and satisfy the government budget balance constraint.

1. Fix Country 2's tax system $(\{a_0^2, a_1^2, \tau_k^2\})$.
2. Fix Country 1's labor income tax parameters, $\{a_0^1, a_1^1\}$.
3. Guess a capital income tax rate for Country 1, τ_k^1 .
4. Guess an after-tax return to capital R .
5. Guess aggregate moments in the economy: the wages $w^i(\theta)$, average labor earnings $\bar{y}^i$ (necessary since labor income tax code is a function of average earnings in the economy), and population ratio (since *per capita* budget constraint has to be satisfied).
6. Solve household problems (both countries).
7. Aggregate and check if the guesses for wages, average labor earnings, and population size coincide.
8. If they do, check if the bond market clears.
 - If not, go back to Step 4, and update guesses for wages, average labor earnings, and population ratio.
9. If the bond market clears, check if the government budget constraint is satisfied.
 - If the bond market does not clear, go back to Step 3, and update the guess for the after-tax return to capital.
10. If the government budget constraint is satisfied, then go back to Step 2, and repeat the procedure for the next set of labor income tax parameters in Country 1.
 - If not, go back to Step 3, and make a new guess for the capital income tax rate.
11. Find the level of $\{a_0^1, a_1^1\}$ and the budget-balancing τ_k^1 that maximize the steady-state welfare of households in Country 1 (Best Response).
12. Taking as given the tax system of Country 1, repeat the procedure (Steps 1 through 11) for Country 2.
13. Iterate until the tax systems arrive at a fixed point.