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Diskussionspapiere der DFG-
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Heterogene Arbeit: Positive und Normative
Aspekte der Qualifikationsstruktur der Arbeit

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Education policy and tax competition with imperfect student and labor mobility

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Education policy and tax competition with imperfect student and labor mobility

Tim Krieger

University of Paderborn
Department of Economics
Warburger Str. 100
33098 Paderborn
Germany

mail: tim.krieger@notes.upb.de
phone: +49 (0) 5251 60 2117
fax: +49 (0) 5251 60 5005

Thomas Lange

ifo Institute for Economic Research at the University of Munich & University of Konstanz
University of Konstanz
Department of Economics
Box D133
78457 Konstanz
Germany

mail: thomas.lange@uni-konstanz.de
phone: +49 (0) 7531 88 2305
fax: +49 (0) 7531 88 4101

Abstract:

In this paper we analyze the effect of increasing labor (i.e. graduates'/academics') and student mobility on net tax revenues when revenue-maximizing governments compete for human capital by means of income tax rates and amenities offered to students (positive expenditure) or rather tuition fees (negative expenditure). We demonstrate that these instruments are strategic complements and that increasing labor mobility due to ongoing globalization not necessarily implies intensified tax competition and an erosion of revenues. On the contrary, the equilibrium tax rate even increases in mobility. Amenities offered to students (or rather tuition fees) may either increase or decrease, and, overall, net revenues increase. An increase in student mobility, however, erodes revenues due to intensified tax and amenity competition.

JEL Classification : I22, J61, F22, H2, H87
Keywords : labor mobility, student mobility, higher education, tax competition, public expenditure competition

Education policy and tax competition with imperfect student and labor mobility*

Tim Krieger†

University of Paderborn

Thomas Lange‡

ifo Institute for Economic Research &

University of Konstanz

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†University of Paderborn, Department of Economics, Warburger Str. 100, D-33098 Paderborn, Germany.

‡Corresponding author. ifo Institute for Economic Research & University of Konstanz, Box D133, D-78457 Konstanz, Germany; E-mail: thomas.lange@uni-konstanz.de

1 Introduction

In most OECD and especially in European countries, tertiary education is to a large extent publicly funded. As shown in Figure 1, except for Japan and the U.S., the share of public funding in higher education (indicated by the dark bars) exceeds 50%. In many European countries this share is even larger than 90%. From a public finance

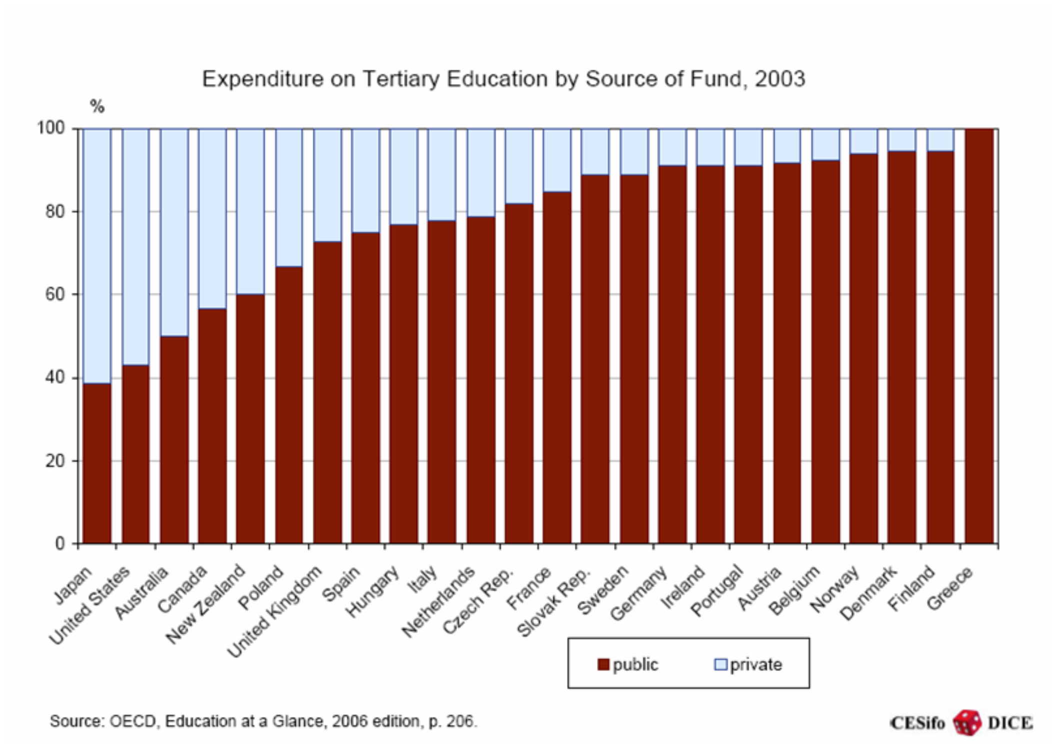

Figure 1: Public and private tertiary education funding, *Source*: DICE (Ifo's Database for Institutional Comparisons in Europe, http://www.ifo.de)

point of view, in times of increasing high-skilled labor mobility, the problem arises that some of those people who benefit from a large publicly funded tertiary education may not pay for their education in terms of income taxes after graduation when they leave the country in order to work abroad. Not only international competition for human capital may cause an erosion of local taxation (see for example Poutvaara, 2000, 2001) but also, as demonstrated for example by Justman and Thisse (1997, 2000), increasing labor mobility may provide an incentive to cut expenditures on public education funding.[1]

[1]Konrad (1995) shows that older citizens prefer to finance immobile public goods such as infrastructure rather than education which is embodied in mobile individuals who avoid taxation by

Things become more interesting when also considering internationally mobile students. Ignoring external effects, student immigration first and foremost could be supposed to impose costs on the host country which highly subsidizes higher education. These costs include resource and administrative costs[2]. At least in EU countries, a discrimination of foreign students, e.g. in the form of (higher) tuition fees, is not allowed[3]. This equal treatment of foreign students may reduce a country's incentive to provide public higher education when foreign students pay taxes in their country of origin after graduating (Del Rey, 2001). Büttner and Schwager (2004) then demonstrate that the introduction of tuition fees could mitigate the potential underprovision of higher education. The fact that student mobility (represented by the number of foreign students enrolled in tertiary education outside their country of origin) increased by nearly 50% in the years from 1998 to 2003 in the OECD countries[4], illustrates the increasing relevance of these aspects. While countries like Australia, the UK, Austria, Germany and France are typical net recipient countries with a considerable share of foreign students, Norway and Ireland for example are net sending countries[5].

It is not only migration influencing national public expenditure and tax policy but also the other way around. In our theoretical analysis, we assume income tax and education policy differentials between countries being determinants of students' and graduates' migration flows. Our paper presents a model of student and labor migration in a (symmetric) two-country setting, allowing to analyze strategic interaction with respect to two policy instruments of two net revenue maximizing governments[6]: (i) education expenditures in the form of an 'amenity' provided to students (we also allow for negative expenditures which we interpret as tuition fees to be paid by students) and (ii) income tax rates. Students have an attachment to their location of education, which can be either the country of origin or the foreign country. This can

emigration.

[2]See for example Throsby (1998) for an overview of costs and benefits of student immigration and emigration.

[3]This is for example different in the U.S. where state universities often charge lower fees for local students.

[4]See OECD (2005, Table C3.6).

[5]See for example OECD (2001, p.102).

[6]We may interpret these governments as Leviathan-type governments which have some (non-specified) self-interest in maximizing net revenues.

for example be explained by social networks and family ties[7]. Dreher and Poutvaara (2005) find empirical evidence for a close relation between student flows and subsequent permanent migration flows. Using data on foreign students in Germany, Hein and Plesch (2007) find that social networks in the country of origin as well as in the foreign (i.e. the host) country play an important role in students' return migration decisions when studying abroad. In our model we capture this by migration costs incurred when leaving the location of education, which can be either positive or negative and which differ between individuals. This is, we allow for the possibility that a certain percentage of foreign students cannot leave the host country due to large migration costs and therefore cannot free-ride on this country's publicly provided education. Analogously, a certain amount of domestic students cannot leave their country of origin and location of education after graduating from university.

In such a setting, the question arises whether countries might have an incentive to attract foreign students in order to increase the expected future tax base. In contrast, countries may want to charge tuition fees in order to guarantee that those who benefitted from the education system also pay for it. In this paper, we analyze the use of fiscal instruments in the context of strategically interacting governments who maximize their jurisdiction's net revenues and evaluate the consequences of globalization in the sense of increasing student and labor mobility on net revenues.

In our two-country-two-instrument competition model with heterogeneous students and graduates[8], we find the following: income tax rates as well as amenities/tuition fees among countries are strategic complements. Furthermore, we find that governmental net revenues need not to decrease with a higher degree of labor mobility. This is due to an equilibrium tax rate increasing effect caused by a reduction of the income elasticity of the number of students in the country. An increase of student mobility, however, erodes net revenues due to intensified competition in both policy instruments.

Our model presents some new insights which extend the literature on higher education policy in the international context. First, we allow for a 'combined' student and labor migration decision, implying that students when making their decision

[7]Our focus here is more on foreign students who also graduate from the university in the host country and not on so called Bologna students who spend only one semester abroad.

[8]Within the group of students and within the group of graduates, individuals differ with respect to migration costs or rather mobility.

with respect to the location of education already consider tax policy and expected migration costs in the future which are the determinants of the labor migration decision at the next stage. In the model of Kemnitz (2005) who analyzes quality effects of tuition fees in a federation considering student and graduate mobility, this effect is ruled out by the assumption that jurisdictions only compete by means of education but not tax policy. Second, we consider some migration cost advantage of 'repatriates' who leave the location of education in order to work in their home country compared to migrants who leave their country of origin for the first time. Both features crucially influence the results. Third, we consider simultaneous competition in two fiscal instruments, including income tax rates, which are often kept fixed in the literature. Exceptions are for example Haupt and Janeba (2007) and Andersson and Konrad (2003). Furthermore, in contrast to Wildasin (2000) for example, we assume that there is no further immobile factor to which the burden of taxation could be (perfectly) shifted.

The structure of our paper is as follows: we introduce our model in chapter 2 and derive students' and graduates' migration decisions. Chapter 3 on tax and amenity/tuition fee competition first of all analyzes the strategic interaction between policy instruments (Section 3.2). Then, we characterize a symmetric equilibrium and derive the effect of increasing student and labor mobility on equilibrium policy instruments and net revenues (Sections 3.3 and 3.4). Chapter 4 briefly discusses some special case where students are assumed to be myopic with respect to tax policy and future migration costs and a variant of the model with respect to the modeling of repatriates' migration decisions. Chapter 5 concludes.

2 Model

Recently, Haupt and Krieger (2007) analyzed the effects of decreasing mobility costs of firms on net tax revenues when two jurisdictions compete for mobile firms with both subsidies and taxes. In such a setting higher firm mobility leads to *higher* net tax revenues. This results from a subsidy reducing effect. In contrast to Haupt and Krieger (2007), our model does not allow governments to use their instruments to discriminate against foreigners (which is a reasonable assumption, at least in the context of the EU); also, we use a different time structure. As a consequence, migration at the first (student migration) stage cannot be treated independently from migration at the second (labor migration) stage.

2.1 General assumptions and time structure

The time structure of the model is as follows. First, the governments of two countries i and j which are identical in all respects, simultaneously set tax rates t_x and an education policy represented by an education expenditure s_x per student, $x \in \{i, j\}$. s can be either positive in which case we call it an 'amenity', or negative so that it can be interpreted as tuition fees. The term amenity captures governmental expenditures which potentially attract students (think for example of specific subsidies – in cash or kind –, scholarships or other grants). As these kinds of expenditures and tuition fees are basically two sides to a coin in our model, most of the time we only refer to the phrase amenities when considering education policy. Students knowing their migration costs m_0 for leaving the country of origin then decide on the location of education. 'Migration costs' in our model not only capture monetary costs (like for instance moving expenses) but also non-monetary costs or rather benefits – which are related to psychological, social and cultural aspects of migration – and therefore represent a student's 'home attachment'[9]. After having earned the university degree, nature reveals the individual migration costs m for leaving the location of education in case the individual studied in his home country, and $(1 - \alpha)m$ with $\alpha \in [0, 1[$ in case that an individual having graduated from a foreign university returns to his location of origin. A non-zero α captures the migration cost advantage of a repatriate compared to a graduate who leaves his home country for the first time. This cost advantage might for example be due to linguistic proficiency, already existing social networks in the home country, faster (re)familiarization etc. Last, university graduates decide on the location of labor supply.

See that if tax rates were set after the student and before the labor migration decision, the government might have an incentive to attract students by announcing low tax rates for the future but to deviate from this policy after some students are 'locked in' within the country due to high individual migration costs. We abstain from this problem, since in a repeated game or rather OLG setting, future genera-

[9]See for example Beckmann and Papageorgiou (1989), Mansoorian and Myers (1993) and Haupt and Peters (2003) who use this concept, or Boneva and Frieze (2001) as an example from the socio-psychological literature.

tions would certainly adjust their behavior in response to deviations from announced policy. Poutvaara (2001) for example justifies the absence of the so called 'hold-up' problem with respect to private education investment based on this argument.[10]

Mobility costs $m_0 \in [\underline{m}_0, \overline{m}_0]$ and $m \in [\underline{m}, \overline{m}]$ are assumed to be uniformly distributed among students and graduates respectively. We assume that the upper limit of each distribution is positive implying that there are always individuals with positive migration costs. Furthermore, it seems reasonable to believe that there are at least some individuals (students and graduates) with negative migration costs, implying a strong desire for migration; i.e. $\underline{m}, \underline{m}_0 < 0$[11]. The corresponding density functions are $f(m_0) = \frac{1}{\Delta m_0}$ and $f(m) = \frac{1}{\Delta m}$ with $\Delta m_0 = (\overline{m}_0 - \underline{m}_0)$ and $\Delta m = (\overline{m} - \underline{m})$. In what follows, we also assume that $\overline{m} > |\underline{m}|$, implying that the expected value of m or rather the average mobility cost is positive:

$$\mathrm{E}\{m\} = \int_{\underline{m}}^{\overline{m}} m f(m) dm = \frac{1}{2}(\overline{m} + \underline{m}) > 0.$$

Hence, a student expects to face positive migration costs when he wants to leave the location of education (which can either be the home or the foreign country) as a graduate. A positive m representing an individual's 'residence attachment' with respect to the location of education is for example due to social ties - especially family ties - and the acquirement of country-specific human capital during the course of ones studies.[12]

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[10]Our assumption that *all* individuals go for education (and kind of exert an identical and exogenously fixed level of effort) directly implies that we assumed away the hold-up problem, which arises in settings with time-consistent taxation and which might be mitigated by interregional competition for human capital. See Boadway, Marceau and Marchand (1996), Andersson and Konrad (2003) and Haupt and Janeba (2007), for instance, considering the hold-up problem.

[11]A repatriate's negative cost could for example be interpreted as 'home sickness' while a first-time-migrant's negative cost reflects some kind of 'adventuresomeness', which not only captures risk loving behavior but for example also career concerns or intercultural interests.

[12]See for example Baruch, Budhwar and Khatri (2007) for an empirical analysis of non-return determinants. Tremblay (2005) provides a more general overview with respect to the relationship between student and high-skilled labor mobility. The relevance of this phenomenon is for example illustrated by high stay rates of foreign doctorate recipients from U.S. universities in the United States (Finn, 2003).

2.2 Individual migration decisions

Figure 2 illustrates the individual decision making process with respect to migration. We derive the migration decisions via backward induction.

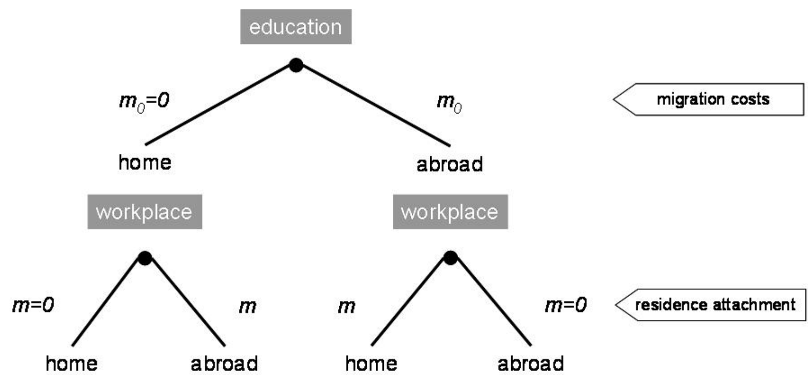

Figure 2: Individual decision making

Labor migration At the second (labor migration) stage, a graduate born and educated in country i, decides to stay in i (leave i) for supplying labor if and only if

$$m > (t_i - t_j)w \qquad (m < (t_i - t_j)w)\,, \tag{1}$$

i.e. if mobility costs exceed (fall short of) the tax differential between the two countries. Gross wage income for inelastically supplied labor is denoted by w. A graduate in i, if born in j, stays in i (or rather repatriates) if

$$(1-\alpha)m > (t_i - t_j)w \qquad ((1-\alpha)m < (t_i - t_j)w)\,. \tag{2}$$

Student migration Whether a student born in country i attends a university in country i depends on the international education expenditure and tax differential, individual migration costs m_0 and expectations about migration costs m revealed at the next stage. We assume risk-neutral individuals here. An individual in country i compares his expected net payoff from studying in i (π_i^i) with the expected payoff when studying abroad (π_j^i). Studying in i yields the following expected net payoff[13]

$$\begin{aligned} \mathrm{E}\{\pi_i^i\} &= \Pr\{m > (t_i - t_j)w\}(1-t_i)w \\ &\quad + \Pr\{m < (t_i - t_j)w\}\left[(1-t_j)w - \mathrm{E}\{m | m < (t_i - t_j)w\}\right] + s_i. \end{aligned} \tag{3}$$

[13]To simplify matters we assume that there is no discounting between periods. This assumptions does not change our results qualitatively.

With probability $\Pr\{m > (t_i - t_j)w\}$ the individual works in country i after graduation and earns net labor income $(1-t_i)w$. With probability $\Pr\{m < (t_i - t_j)w\}$ the individual leaves i to work in j and earns net labor income $(1-t_j)w$ there. The corresponding expected migration costs are $\mathrm{E}\{m|m < (t_i - t_j)w\}$. When studying in i, the individual benefits from education expenditure $s_i > 0$ or rather has to pay tuition fees $s_i < 0$.

Analogously, studying in j yields

$$\begin{aligned}\mathrm{E}\{\pi_j^i\} &= \Pr\{(1-\alpha)m > (t_j - t_i)w\}(1-t_j)w \\ &\quad + \Pr\{(1-\alpha)m < (t_j - t_i)w\} \\ &\quad \times [(1-t_i)w - \mathrm{E}\{(1-\alpha)m|(1-\alpha)m < (t_j - t_i)w\}] + s_j - m_0. \quad (4)\end{aligned}$$

With probability $\Pr\{(1-\alpha)m > (t_j - t_i)w\}$ the individual stays in j after studying there. With probability $\Pr\{(1-\alpha)m < (t_j - t_i)w\}$ he returns to his country of origin. The student incurs migration costs m_0 at the first (student migration) stage.

A student born in i attends a university in country i if and only if $\mathrm{E}\{\pi_i^i\} > \mathrm{E}\{\pi_j^i\}$. Using the probabilities and expected migration costs[14] in (3) and (4) and solving for m_0 yields after some manipulations the following condition:

$$m_0 > (s_j - s_i) + \frac{(\overline{m} + \underline{m})w}{\Delta m}(t_i - t_j) - \frac{\left[(t_i - t_j)^2 w^2 \left(1 - \frac{1}{(1-\alpha)}\right) + \alpha \underline{m}^2\right]}{2\Delta m}. \quad (5)$$

Of course, the lower the amenity in the country of origin relative to the amenity abroad, the more students leave the country. Ignoring the third term on the RHS, which is related to the repatriates' migration cost advantage and which vanishes for $\alpha = 0$, the higher the tax rate in the country of origin relative to the foreign tax rate, the higher student emigration. This holds for the assumed positive expected value of migration costs m. The reason is that people anticipate that they might not be able to escape from unfavorable taxation at the next stage, so that there is a tendency to do so already at the first stage. Furthermore, the lower expected labor mobility costs at the second stage, i.e. the higher expected labor mobility, the less considerable is this effect in the student migration decision, implying a lower student mobility. The third term captures the effect of the repatriates' migration cost advantage on the expected payoff of studying abroad. The sign of this term is a priori ambiguous.

[14] See the Appendix for the explicit values.

3 Tax and education policy competition

After presenting the basic set-up of the fiscal competition model, this chapter deals with the strategic interaction of governments, the equilibrium policy and comparative static effects.

3.1 Basic set-up

The government in each jurisdiction maximizes local net revenues, i.e. tax revenue minus education amenities (plus tuition fees respectively), minus some variable cost of education depending on the number of students in country i. The parameter c denotes this variable cost per student which is not restricted to be non-negative. Normalizing the size of population in each country to one, country i's net-revenue can be written as

$$R_i \equiv t_i w \underbrace{\left(P_i^{ii} + P_j^{ii} + P_i^{ji} + P_j^{ji}\right)}_{\equiv L_i} - (s_i + c) \underbrace{\left(\Gamma_i + (1 - \Gamma_j)\right)}_{\equiv \Psi_i} \tag{6}$$

with P_a^{bi}, $a, b \in \{i, j\}$, denoting the probability of an individual born in a and educated in b, to work in i. With the population size normalized to one, the sum within brackets in the first term in (6) represents the labor force in country i (multiplied with the wage per worker constituting i's tax base), which we will denote by L_i in what follows. Γ_a represents the number of individuals born in country a who attend a university in a. Hence, $(1 - \Gamma_a)$ is the number of students leaving the country and $\Psi_i \equiv \Gamma_i + (1 - \Gamma_j)$ represents the total number of both foreign and domestic students in country i. With our assumption of uniformly distributed migration costs, we can express the size of each of four different groups constituting total labor force in i:

$$P_i^{ii} \equiv \frac{[\overline{m} - (t_i - t_j)w]}{\Delta m}\Gamma_i \ , \qquad P_j^{ii} \equiv \frac{[\overline{m} - \frac{(t_i - t_j)w}{(1-\alpha)}]}{\Delta m}(1 - \Gamma_j) \ ,$$

$$P_i^{ji} \equiv \frac{[\frac{(t_j - t_i)w}{(1-\alpha)} - \underline{m}]}{\Delta m}(1 - \Gamma_i) \ , \qquad P_j^{ji} \equiv \frac{[(t_j - t_i)w - \underline{m}]}{\Delta m}\Gamma_j .$$

The numbers of students are

$$\begin{aligned}
\Gamma_i &\equiv \frac{1}{\Delta m_0}\left[\overline{m}_0 - (s_j - s_i) - \frac{(\overline{m} + \underline{m})(t_i - t_j)w}{\Delta m} + \frac{[(t_i - t_j)^2 w^2 A + \alpha \underline{m}^2]}{2\Delta m}\right], \\
(1 - \Gamma_i) &= \frac{1}{\Delta m_0}\left[(s_j - s_i) + \frac{(\overline{m} + \underline{m})(t_i - t_j)w}{\Delta m} - \frac{[(t_i - t_j)^2 w^2 A + \alpha \underline{m}^2]}{2\Delta m} - \underline{m}_0\right],
\end{aligned}$$

where $A \equiv (1 - \frac{1}{(1-\alpha)})$. Γ_j and $(1 - \Gamma_j)$ can be expressed analogously. See that neither taxes nor amenities discriminate against foreigners.

Governments maximize local net revenues. Since those can be demonstrated to be always positive in equilibrium (see Lemma 1 in Section 3.3), we do not account for budget constraints (see e.g. Andersson and Konrad, 2003). The first order conditions of government i's optimization problem

$$\max_{t_i, s_i} R_i = R_i(t_i, s_i; t_j, s_j)$$

are

$$\frac{\partial R_i}{\partial t_i} = wL_i + t_i w \frac{\partial L_i}{\partial t_i} - (s_i + c)\frac{\partial \Psi_i}{\partial t_i} = 0, \tag{7}$$

$$\frac{\partial R_i}{\partial s_i} = t_i w \frac{\partial L_i}{\partial s_i} - \Psi_i - (s_i + c)\frac{\partial \Psi_i}{\partial s_i} = 0. \tag{8}$$

The optimal tax rate equalizes the marginal costs and benefits of taxation. An increase in t_i reduces the tax base by (i) reducing the number of (domestic and foreign) students in country i and (ii) reducing the number of individuals staying in i after their education and reducing the number of immigrants and repatriates with a foreign university certificate. The second term in (7) represents this effect, which is the marginal cost of taxation. The marginal benefits can be decomposed into a simple tax rate effect (first term), a cost reducing (if $c > 0$) and an amenity reducing effect (third term) which is due to the reduced number of students in i. If, however, s_i is negative and therefore has to be interpreted as tuition fees, this latter effect, of course, belongs to the marginal *cost* component.

The optimal amenity equalizes the marginal costs and benefits of providing the amenity. An increase in the amenity broadens the tax base through attracting students and therefore – ceteris paribus – increasing the number of individuals working and paying taxes in i. This effect, represented by the first term in (8), is the marginal benefit of providing the amenity. However, an increase in the amenity also increases governmental expenditures through a simple direct effect and an indirect one due to the increased number of students. The second and third term in (8) represent these marginal costs of providing the amenity. Table 1 summarizes the policy instruments' marginal costs and benefits, whereas cases (I) and (II) differ in the sign and therefore the interpretation of s as either amenity or tuition fee.

	instrument	marginal costs	marginal benefits
(I) $s > 0$	tax rate	reduction of tax base	direct tax rate effect, expenditure reduction
	amenity	direct effect, indirect effect (no. of students)	increasing tax base
(II) $s < 0$	tax rate	reduction of tax base fee revenue reducing effect	direct tax rate effect,
	tuition fee	reduction of tax base, indirect effect (no. of students)	direct effect

Table 1: The policy instruments' marginal costs and benefits

The reaction of country i's labor force and the number of students on a policy change, i.e. $\frac{\partial \Psi_i}{\partial y}$ and $\frac{\partial L_i}{\partial y}$, $y \in \{t_i, s_i\}$, can be calculated as follows. Consider the number of students first.

$$\frac{\partial \Psi_i}{\partial s_i} = \frac{\partial}{\partial s_i}(\Gamma_i + (1 - \Gamma_j)) = \frac{2}{\Delta m_0} > 0 \quad \text{and} \quad \frac{\partial \Psi_i}{\partial t_i} = -\frac{2(\overline{m} + \underline{m})w}{\Delta m \Delta m_0} < 0, \tag{9}$$

i.e. the number of students increases with the amenity and decreases in the tax rate. The latter effect reflects the fact that students anticipate that they may only be imperfectly mobile after having graduated from university. The size of the labor force reacts in the following way:

$$\frac{\partial L_i}{\partial s_i} = \frac{2(\overline{m} + \underline{m})}{\Delta m \Delta m_0} > 0, \tag{10}$$

$$\frac{\partial L_i}{\partial t_i} = -\frac{w}{\Delta m}\left[\Gamma_i + \Gamma_j + \frac{(1-\Gamma_i) + (1-\Gamma_j)}{(1-\alpha)}\right] - \frac{2(\overline{m} + \underline{m})^2 w}{\Delta m^2 \Delta m_0}$$

$$- \frac{2(t_i - t_j)^2 w^3}{\Delta m^2 \Delta m_0} A^2 < 0. \tag{11}$$

The number of workers (and therefore taxpayers) in country i increases in the amenity offered to students and decreases in the tax rate.

3.2 Strategic interaction

We are now interested in the optimal (simultaneous) reaction of t_i and s_i in case of a change of one of the other country's instruments t_j and s_j. We state the following proposition.

Proposition 1 *In a symmetric Nash-equilibrium, the income tax rates are strategic complements. The same holds for the amenities for students (or rather tuition fees). However, a country's tax rate does not react on a change of the foreign amenity and, analogously, a country's amenity does not react on a change of the foreign tax rate.*

Proof.

More generally, the two first order conditions can be written as

$$R^t(t_i, s_i; t_j, s_j) = 0, \quad (12)$$
$$R^s(t_i, s_i; t_j, s_j) = 0. \quad (13)$$

In order to derive the comparative static effects $\frac{\partial t_i}{\partial s_j}$, $\frac{\partial s_i}{\partial s_j}$, $\frac{\partial t_i}{\partial t_j}$ and $\frac{\partial s_i}{\partial t_j}$ we apply the implicit-function theorem. The Jacobian of the system of equations (12) and (13) which is the Hessian matrix of the net revenue function R_i is

$$\mathbf{H} = \begin{bmatrix} \frac{\partial R^t}{\partial t_i} & \frac{\partial R^t}{\partial s_i} \\ \frac{\partial R^s}{\partial t_i} & \frac{\partial R^s}{\partial s_i} \end{bmatrix}. \quad (14)$$

Totally differentiating (12) and (13) and setting $dt_j = 0$, in matrix notation we get

$$\mathbf{H} \cdot \begin{bmatrix} \frac{\partial t_i}{\partial s_j} \\ \frac{\partial s_i}{\partial s_j} \end{bmatrix} = \begin{bmatrix} -\frac{\partial R^t}{\partial s_j} \\ -\frac{\partial R^s}{\partial s_j} \end{bmatrix}. \quad (15)$$

By Cramer's rule, we can derive the following comparative static effects

$$\frac{\partial t_i}{\partial s_j} = \frac{\det(\mathbf{H}_1^s)}{\det(\mathbf{H})} \quad \text{and} \quad \frac{\partial s_i}{\partial s_j} = \frac{\det(\mathbf{H}_2^s)}{\det(\mathbf{H})}. \quad (16)$$

The Hessian determinant is[15]

$$\det(\mathbf{H}) = \frac{16w^2}{\Delta m \Delta m_0^2} \left(\overline{m}_0 - \frac{\underline{m}_0}{(1-\alpha)} + \frac{\alpha A \underline{m}^2}{2\Delta m} \right). \quad (17)$$

In what follows, we use the following notation: $\Delta \widetilde{m_0} \equiv \overline{m}_0 - \frac{\underline{m}_0}{(1-\alpha)} + \frac{\alpha A \underline{m}^2}{2\Delta m}$. See that for $\alpha = 0$, $\Delta \widetilde{m_0}$ coincides with Δm_0. With our assumption of $\underline{m}_0 < 0$,

[15]Please refer to the Appendix for some hints with respect to calculations in what follows.

$(\overline{m}_0 - \frac{m_0}{(1-\alpha)}) > 0$. However, since $A = 1 - \frac{1}{(1-\alpha)} < 0$ for $\alpha > 0$, without further assumptions on α or rather $\underline{m}$ the overall sign of $\Delta\widetilde{m_0}$ and therefore $\det(\mathbf{H})$ is ambiguous. In order to guarantee that $\det(\mathbf{H}) > 0$, we assume $\Delta\widetilde{m_0} > 0$, which is for example guaranteed by an α which is not too large. With this assumption, the signs of the Hessian determinant's principal minors, $sgn[\det(\mathbf{H}_I) = \frac{\partial R^t}{\partial t_i}] < 0$ and $sgn[\det(\mathbf{H}_{II}) = \det(\mathbf{H})] > 0$, guarantee the optimal values of t_i and s_i to be really net revenue *maximizing*.

Furthermore,

$$\det(\mathbf{H}_1^s) = 0 \ , \quad \det(\mathbf{H}_2^s) = \frac{8w^2\Delta\widetilde{m_0}}{\Delta m \Delta m_0^2}. \tag{18}$$

Using these determinants in (16) we can state our first result

$$\frac{\partial t_i}{\partial s_j} = 0 \quad \text{and} \quad \frac{\partial s_i}{\partial s_j} = \frac{1}{2} > 0. \tag{19}$$

This proves that the subsidies are strategic complements while the tax rate t_i does not react on a change in the foreign subsidy s_j.

Next, we derive country i's optimal reaction in case of a change in the foreign tax rate t_j. Totally differentiating (12) and (13) and setting $ds_j = 0$, we get

$$\mathbf{H} \cdot \begin{bmatrix} \frac{\partial t_i}{\partial t_j} \\ \frac{\partial s_i}{\partial t_j} \end{bmatrix} = \begin{bmatrix} -\frac{\partial R^t}{\partial t_j} \\ -\frac{\partial R^s}{\partial t_j} \end{bmatrix}. \tag{20}$$

Again, by Cramer's rule, we can derive

$$\frac{\partial t_i}{\partial t_j} = \frac{\det(\mathbf{H}_1^t)}{\det(\mathbf{H})} \quad \text{and} \quad \frac{\partial s_i}{\partial t_j} = \frac{\det(\mathbf{H}_2^t)}{\det(\mathbf{H})}, \tag{21}$$

where

$$\det(\mathbf{H}_1^t) = \frac{8w^2\Delta\widetilde{m_0}}{\Delta m \Delta m_0^2} \ , \quad \det(\mathbf{H}_2^t) = 0. \tag{22}$$

Therefore,

$$\frac{\partial t_i}{\partial t_j} = \frac{1}{2} > 0 \quad \text{and} \quad \frac{\partial s_i}{\partial t_j} = 0. \tag{23}$$

This proves that the tax rates are strategic complements, while the subsidy s_i does not react on a change in the foreign tax rate t_j. ■

Our results of strategic complementarity are consistent with empirical studies on fiscal policy interdependencies. In a seminal contribution, Case, Hines and Rosen (1993) find that (e.g. education) expenditures of U.S. states are significantly and positively influenced by their neighbor states' expenditures. A more recent study by Redoano (2007) – among other things – analyzes the fiscal interaction among 17 European countries through income tax rates and public education expenditures and also supports the strategic complementarity of instruments.

The fact that the 'cross-effects', i.e. $\frac{\partial t_i}{\partial s_j}$ and $\frac{\partial s_i}{\partial t_j}$, are zero is basically due to our symmetry assumptions and the modeling of tax policy which is assumed to cause solely one 'distortion', namely emigration.

3.3 Equilibrium

Let us determine the tax rate, amenity and net revenue in a symmetric Nash-equilibrium ($t_i = t_j = t^*$, $s_i = s_j = s^*$). Equilibrium values are indicated by asterisks. The first order condition for t^* amounts to

$$R^{t^*} = w + t^* w \left(-\frac{2(\overline{m} + \underline{m})^2 w}{\Delta m^2 \Delta m_0} - \frac{2w \Delta \widetilde{m_0}}{\Delta m \Delta m_0} \right) + (s^* + c) \frac{2(\overline{m} + \underline{m}) w}{\Delta m \Delta m_0} = 0. \quad (24)$$

Furthermore, in equilibrium, the first order condition for the amenity reads

$$R^{s^*} = \frac{2(\overline{m} + \underline{m})}{\Delta m \Delta m_0} t^* w - 1 - (s^* + c) \frac{2}{\Delta m_0} = 0. \quad (25)$$

Explicit combined solution Our assumption of uniformly distributed migration costs allows us to derive the equilibrium values explicitly, only depending on parameters. From (25) we can derive the equilibrium amenity as a function of the tax rate:

$$s^* = \frac{(\overline{m} + \underline{m})}{\Delta m} t^* w - \frac{\Delta m_0}{2} - c. \quad (26)$$

For positive expected migration costs at the labor migration stage, the amenity increases in the tax rate. Furthermore, it increases in the expected migration costs m and the sensitivity of the number of students to education policy (remember that $\frac{\partial \Psi}{\partial s} = \frac{2}{\Delta m_0}$); the amenity decreases in the marginal cost of an additional student studying in a country. Using (26) in (24) yields the combined first order condition for the equilibrium tax rate

$$w + t^* w \left[-\frac{2(\overline{m} + \underline{m})^2 w}{\Delta m^2 \Delta m_0} - \frac{2w \Delta \widetilde{m_0}}{\Delta m \Delta m_0} \right] + \frac{2(\overline{m} + \underline{m}) w}{\Delta m \Delta m_0} \left[\frac{(\overline{m} + \underline{m})}{\Delta m} t^* - \frac{\Delta m_0}{2} \right] = 0, \quad (27)$$

which can easily be solved for t^*:

$$t^* \quad = \quad \frac{1 - \frac{(\overline{m}+\underline{m})}{\Delta m}}{\frac{2w}{\Delta m \Delta m_0}(\overline{m}_0 - \frac{m_0}{(1-\alpha)} + \frac{\alpha A \underline{m}^2}{2\Delta m})} = \frac{1 - \frac{(\overline{m}+\underline{m})}{\Delta m}}{\frac{2w\Delta \widetilde{m_0}}{\Delta m \Delta m_0}}. \quad (28)$$

With the equilibrium amenity and tax rate from (26) and (28) we can also determine the governmental equilibrium net revenue

$$R^* \quad = \quad t^* w - (s^* + c) = \left(1 - \frac{(\overline{m} + \underline{m})}{\Delta m}\right) t^* w + \frac{\Delta m_0}{2}. \quad (29)$$

From (28) and (29) we can directly verify the following Lemma on the sign of the equilibrium tax rate and net revenue:

Lemma 1 *Our assumptions that $\underline{m} < 0$ and $\Delta \widetilde{m_0} > 0$ are sufficient conditions for the equilibrium tax rate t^* to be positive. Furthermore, even with a positive amenity s^*, net revenue R^* is also always strictly positive in a symmetric equilibrium.*

Elasticity notation At this stage, let us reconsider the combined first order condition in equilibrium and use an elasticity notation in the derivation of the equilibrium tax rate. This reveals the driving forces behind the equilibrium result more clearly and facilitates the intuition for the comparative statics results presented in Section 3.4. We can express (27) more generally as

$$w + t^* w \frac{\partial L_i}{\partial t_i}\bigg|_{\text{(equ.)}} - \frac{\partial \Psi_i}{\partial t_i}\bigg|_{\text{(equ.)}} \left[\frac{(\overline{m} + \underline{m})}{\Delta m} t^* - \left(\frac{\partial \Psi_i}{\partial s_i} \right)^{-1} \bigg|_{\text{(equ.)}} \right] = 0. \quad (30)$$

We will suppress indices and equilibrium indications in order to keep the following expressions clear. First of all, see that we can decompose the tax base effect of tax policy into two components:

$$\frac{\partial L}{\partial t} = \widehat{\frac{\partial L}{\partial t}} + \overline{\frac{\partial L}{\partial t}},$$

where $\widehat{\frac{\partial L}{\partial t}} := -\frac{2w\Delta \widetilde{m_0}}{\Delta m \Delta m_0}$ captures the direct effect on the size of the labor force, while $\overline{\frac{\partial L}{\partial t}} := -\frac{2(\overline{m}+\underline{m})^2 w}{\Delta m^2 \Delta m_0}$ reflects the effect which can be traced back to the reduced number of students. We can rewrite this latter effect as $\overline{\frac{\partial L}{\partial t}} = \theta \frac{\partial \Psi}{\partial t}$, where $\theta := \frac{(\overline{m}+m)}{\Delta m} > 0$ may be interpreted as the degree with which the change in the number of students is reflected in the change of the the tax base. With $\underline{m} = 0$, in equilibrium (implying equalized tax rates) there is basically no migration incentive for graduates and therefore a change in the number of students translates one-to-one into the change of the labor force size ($\theta = 1$). This is not the case for $\underline{m} < 0$ where at least some individuals emigrate even in case of no tax differential, implying $\theta < 1$. In the combined first order condition, however, this effect cancels out and we are left with

$$w + t^* w \frac{\widehat{\partial L}}{\partial t} + \frac{\partial \Psi}{\partial t} \left(\frac{\partial \Psi}{\partial s} \right)^{-1} = 0.$$

Referring to $\omega := (1-t)w$ as net labor income, this condition may be reformulated as

$$w + t^* w \frac{\widehat{\partial L}}{\partial \omega} \frac{\partial \omega}{\partial t} + \frac{\partial \Psi}{\partial \omega} \frac{\partial \omega}{\partial t} \left(\frac{\partial \Psi}{\partial s} \right)^{-1} = 0.$$

Multiplying the equation by $(1-t)$ and solving for t^*, yields an implicit solution for the equilibrium tax rate depending on the income elasticity of the tax base ($\epsilon_{L\omega} = \frac{\widehat{\partial L}}{\partial \omega} \frac{\omega}{L} > 0$) and the number of students ($\epsilon_{\Psi\omega} = \frac{\partial \Psi}{\partial \omega} \frac{\omega}{\Psi} > 0$)[16]:

$$t^* = \frac{1 - \epsilon_{\Psi\omega} \left(w \frac{\partial \Psi}{\partial s} \right)^{-1}}{1 + \epsilon_{L\omega}}.$$

As expected, the more elastic students and graduates react on interregional net income differentials, the more intensive is tax competition and the lower the equilibrium tax rate (ceteris paribus):

Proposition 2 *The equilibrium tax rate decreases in the income elasticity of the labor force and the number of students. Furthermore, the tax rate increases in the sensitivity of the number of students to education policy (as represented by $\frac{\partial \Psi}{\partial s}$), which is mainly due to increased expenditures.*

3.4 Comparative statics

Apparently, the degree of labor mobility or rather residence attachment as represented by labor mobility costs m and the degree of student migration are the main determinants of the equilibrium outcome with respect to policy instruments and net revenues.

[16] See that we used the fact that $\Psi^* = L^* = 1$ here.

Labor mobility Consider labor migration costs m first. We state the following proposition.

Proposition 3 *In a symmetric equilibrium, the income tax rate increases with labor mobility. Furthermore, for low degrees of labor mobility, an increase of mobility increases the equilibrium amenity, while for higher degrees of mobility a further increase leads to a decrease of the amenity. Overall, net revenues increase with labor mobility.*

We analyze the effects of changing labor mobility by means of a shift of the mobility costs' support, i.e. we change $\underline{m}$, for a constant Δm implying $\frac{d\overline{m}}{d\underline{m}} = 1$. The effect on the equilibrium tax rate is unambiguous:

$$\left.\frac{\partial t^*}{\partial \underline{m}}\right|_{d\Delta m=0} = -\left[\frac{\frac{2\Delta\widetilde{m_0}}{\Delta m} + \frac{\alpha A\underline{m}}{\Delta m}(1 - \frac{(\overline{m}+\underline{m})}{\Delta m})}{(\frac{2w\Delta\widetilde{m_0}^2}{\Delta m\Delta m_0})}\right] < 0. \tag{31}$$

Note that here and in the following, $\underline{m} < 0$ and $\Delta\widetilde{m_0} > 0$ are sufficient conditions to determine the comparative statics' effects unambiguously. A marginal decrease of $\underline{m}$ implying a decrease of the average mobility cost or rather an increase of labor mobility, *increases* the equilibrium tax rate. This result may seem counterintuitive at first sight. Remembering the elasticity notation of the combined first order condition and the related discussion helps to understand the result. An increase of labor mobility in fact *decreases* students' income elasticity:

$$\left.\frac{\partial \epsilon_{\Psi\omega}}{\partial \underline{m}}\right|_{d\Delta m=0,dt^*=0} = \frac{4\omega}{\Delta m\Delta m_0} > 0.$$

The reason is that higher mobility at the labor migration stage makes the evasion from high taxation easier and students when making their migration decision already recognize this fact. Ceteris paribus, this drives up the tax rate. Furthermore, see that (at least for $\alpha \neq 0$) also $\epsilon_{L\omega}$ decreases with labor mobility and therefore the tax rate increases:

$$\left.\frac{\partial \epsilon_{L\omega}}{\partial \underline{m}}\right|_{d\Delta m=0,dt^*=0} = \frac{2\omega\alpha A\underline{m}}{\Delta m^2\Delta m_0} > 0.$$

The equilibrium amenity also changes with decreasing migration costs:

$$\left.\frac{\partial s^*}{\partial \underline{m}}\right|_{d\Delta m=0} = \frac{(\overline{m}+\underline{m})w}{\Delta m}\left(\left.\frac{\partial t^*}{\partial \underline{m}}\right|_{d\Delta m=0}\right) + \frac{2w}{\Delta m}t^*. \tag{32}$$

The direction of this change depends on the relative size of two effects. One effect goes into the same direction as the effect on the tax rate (first summand) while the second one (second summand) countervails this effect. Ceteris paribus, the higher the tax rate, the higher the benefit from attracting a student as potential tax payer in the future. However, for given tax policy, an increase of labor mobility reduces a jurisdiction's incentive to offer an amenity to attract students, as the attraction of students becomes less effective in attracting future tax payers (due to their higher emigration propensity).

Let us evaluate the derivative at $\alpha = 0$ in order to highlight the main insight.

$$\left.\frac{\partial s^*}{\partial \underline{m}}\right|_{d\Delta m=0}^{\alpha=0} = -\frac{2(\mathrm{E}\{m\}+\underline{m})}{\Delta m} \begin{cases} \geq 0 & \text{if} \quad \mathrm{E}\{m\} \leq -\underline{m} \\ < 0 & \text{if} \quad \mathrm{E}\{m\} > -\underline{m} \end{cases} . \tag{33}$$

While for high average mobility costs, i.e. low degrees of labor mobility, an increase of mobility increases the equilibrium amenity, for higher degrees of mobility a further increase leads to a decrease of the amenity.

Let us put the effects on the tax rate and the amenity together and see how the equilibrium net revenue evolves with increasing labor mobility[17]:

$$\begin{aligned} \left.\frac{\partial R^*}{\partial \underline{m}}\right|_{d\Delta m=0} &= \left(\left.\frac{\partial t^*}{\partial \underline{m}}\right|_{d\Delta m=0}\right) w - \left.\frac{\partial s^*}{\partial \underline{m}}\right|_{d\Delta m=0} \\ &= \left(1 - \frac{(\overline{m}+\underline{m})}{\Delta m}\right)\left(\left.\frac{\partial t^*}{\partial \underline{m}}\right|_{d\Delta m=0}\right) w - \frac{2w}{\Delta m} t^* < 0. \end{aligned} \tag{34}$$

A decrease of mobility costs, i.e. an increase of labor mobility, increases equilibrium net revenues. This is mainly due to increased revenue from taxation. Even if expenditures in form of the amenity were increased, the higher tax revenue would overcompensate the expenditure increase. This result is in line with the findings by Haupt and Krieger (2007).

Student mobility Let us now repeat the same exercise with student migration costs. We state the following proposition:

[17] See that R^* also represents the overall net fiscal burden imposed on individuals studying *and* working in a country.

Proposition 4 *In a symmetric equilibrium and for a positive α, the tax rate and the amenity decrease (or rather tuition fees increase) in student mobility. Overall, the net revenue decreases.*

See that

$$\left.\frac{\partial t^*}{\partial \underline{m}_0}\right|_{d\Delta m_0=0} = -\frac{t^*(1-\frac{1}{(1-\alpha)})}{\Delta \widetilde{m}_0} \begin{cases} = 0\ , & \alpha = 0 \\ > 0\ , & \alpha \neq 0 \end{cases} . \tag{35}$$

For a non-zero α, t^* decreases in student mobility. This result can be traced back to the effect of student mobility on the income elasticity of the size of the labor force. With

$$\left.\frac{\partial \epsilon_{L\omega}}{\partial \underline{m}_0}\right|_{d\Delta m_0, dt^*=0} = \frac{2\omega(1-\frac{1}{(1-\alpha)})}{\Delta m \Delta m_0} < 0.$$

there is a downward pressure on the tax rate, as demonstrated in Section 3.3.

Having derived the effect on the tax rate, higher student mobility can easily be shown to have a decreasing effect on the amenity:

$$\left.\frac{\partial s^*}{\partial \underline{m}_0}\right|_{d\Delta m_0=0} = \frac{(\overline{m}+\underline{m})w}{\Delta m}\left(\left.\frac{\partial t^*}{\partial \underline{m}_0}\right|_{d\Delta m_0=0}\right) \begin{cases} = 0\ , & \alpha = 0 \\ > 0\ , & \alpha \neq 0 \end{cases} . \tag{36}$$

Obviously, for the net revenue to decrease in student mobility, the tax revenue decreasing effect has to dominate the decrease of the amenity. This can be proved to be always the case:

$$\left.\frac{\partial R^*}{\partial \underline{m}_0}\right|_{d\Delta m_0=0} = \left(1-\frac{(\overline{m}+\underline{m})}{\Delta m}\right)\left(\left.\frac{\partial t^*}{\partial \underline{m}_0}\right|_{d\Delta m_0=0}\right) \geq 0. \tag{37}$$

For $\alpha = 0$, net revenue is not affected by student mobility.

4 Extensions and variants

This chapter briefly discusses two extensions or rather variants of our model concerning migration decisions. In doing so, we show that our main results regarding the consequences of increasing international mobility hold.

4.1 Myopic students

Suppose students when making their decision with respect to the location of education to be completely myopic regarding taxes to be payed in the future and migration costs incurring in case of leaving the location of education. In such a setting, a student's migration decision solely depends on migration costs m_0 and the amenity differential between countries. Adjusting the first order conditions for optimal tax and education policy, we find that the optimal tax rate in equilibrium is now independent of the amenity:

$$t^{\circ} = \frac{1}{\frac{2w}{\Delta m \Delta m_0}(\overline{m}_0 - \frac{\underline{m}_0}{(1-\alpha)})} > 0, \tag{38}$$

while the first order condition for the amenity remains unaffected. Again, we can also express the tax rate implicitly and depending on the income elasticity of the labor force:

$$\frac{t^{\circ}}{1-t^{\circ}} = \frac{1}{\epsilon^{\circ}_{L\omega}} > 0.$$

The more elastic the tax base is with respect to net income, the lower the tax rate. However, the tax rate is now independent of the degree of labor mobility, i.e. $\frac{\partial t^{\circ}}{\partial \underline{m}}|_{d\Delta m=0} = 0$. Since the equilibrium amenity is unambiguously decreasing in labor mobility ($\frac{\partial s^{\circ}}{\partial \underline{m}}|_{d\Delta m=0} = \frac{2w}{\Delta m} t^{\circ} > 0$), net revenues unambiguously increase. The qualitative effects of an increase in student mobility on the policy instruments in equilibrium and net revenues remain unchanged.

In a setting with myopic students, the tax rate becomes of course ineffective in attracting students. Or the other way around, an increasing tax rate does not induce an outflow of students implying that the reduction-of-tax-base effect only consists of the emigration of graduates. Therefore, we would expect that in a world of myopic students there is more scope for high taxation than in a world as described above in the main part of the paper. Comparing (28) and (38),

$$t^{\circ} > t^{*} \qquad \text{if} \qquad \frac{(\overline{m} + \underline{m})}{\Delta m}\left(\overline{m}_0 - \frac{\underline{m}_0}{(1-\alpha)}\right) + \frac{\alpha A \underline{m}^2}{2\Delta m} > 0, \tag{39}$$

which holds for a sufficiently small α [18].

[18] Note that $\Delta\widetilde{m_0} = \overline{m}_0 - \frac{\underline{m}_0}{(1-\alpha)} + \frac{\alpha A \underline{m}^2}{2\Delta m} > 0$ is not a sufficient condition. This is due to our assumption of $\underline{m} < 0$, implying $\frac{(\overline{m}+\underline{m})}{\Delta m} < 1$.

4.2 Repatriates' migration cost advantage

The second variant of our model concerns the repatriates' migration cost advantage. While having modeled this advantage in the main part of this paper as a percentage of first-time-migrants' costs, a natural alternative would have been to apply a discount to a repatriate's migrations costs, such that a graduate in i (if born in j) stays in i if and only if

$$m - \beta > (t_i - t_j)w, \tag{40}$$

where $\beta \geq 0$ is the discount. For positive migration costs m, both variants – the $(1-\alpha)$- as well as the β-variant – imply that repatriates have a higher mobility. The variants' implications differ, however, for negative migration costs. While the $(1-\alpha)$-variant implies that a repatriate's home sickness (for equal m) falls short of a first-time-migrant's adventuresomeness, the β-variant implies exactly the opposite. As a matter of fact, distinguishing the two variants would certainly be an interesting empirical issue. Nevertheless, the main result of our analysis, namely the increase in net revenues in case of increasing graduate mobility remains valid.

We only present the most important results of the alternative calculation here. First of all, see that $\mathrm{E}\{\pi_j^i\}$ in the student's migration decision changes. A student born in i then attends a university in i if

$$m_0 > (s_j - s_i) + \frac{(\overline{m} + \underline{m})w}{\Delta m}(t_i - t_j) - \frac{\beta}{\Delta m}\left[(t_i - t_j)w - \frac{\beta}{2} + \underline{m}\right]. \tag{41}$$

See that migration decisions (5) and (41) only differ in the third term on the RHS (which vanishes in both variants for a zero cost advantage of repatriates, i.e. $\alpha = 0$ and $\beta = 0$). Interestingly, an increase in the repatriates' migration cost advantage has different effects in the student migration decision. While a higher cost advantage increases students' migration propensity in the β-variant, the expected payoff from studying abroad decreases in the $(1-\alpha)$-variant. The size of two opposing effects is the key to this result. Ceteris paribus, the direct effect of an increasing repatriation cost advantage increases the expected payoff from studying abroad. However, there is an indirect effect through the probability of repatriating (which is increased), increasing expected migration costs. Overall, the expected payoff from studying abroad may either increase or decrease. While the indirect (negative) effect dominates the direct (positive) one in the $(1-\alpha)$-variant, the opposite is true for the

β-variant: see that differentiating $\mathrm{E}\{\pi_j^i\}$ with respect to α or rather β and evaluating this at the symmetric equilibrium yields

$$\left.\frac{\partial\, \mathrm{E}\{\pi_j^i\}}{\partial \alpha}\right|_{\text{(equ.)}} = -\frac{\underline{m}^2}{2\Delta m} < 0 \quad \text{and} \quad \left.\frac{\partial\, \mathrm{E}\{\pi_j^i\}}{\partial \beta}\right|_{\text{(equ.)}} = \frac{\beta - \underline{m}}{\Delta m} > 0.$$

Nevertheless, and this is the main insight from this paragraph, our main result from above does not change. The equilibrium values of the policy instruments can be calculated as

$$s^\star = \frac{[(\overline{m} + \underline{m}) - \beta]w}{\Delta m} t^\star - \frac{\Delta m_0}{2} - c \tag{42}$$

and

$$t^\star = \frac{1 - \frac{[(\overline{m}+\underline{m})-\beta]}{\Delta m}}{\frac{2w}{\Delta m}} = \frac{1}{w}\left(\frac{\beta}{2} - \underline{m}\right) > 0. \tag{43}$$

It can easily be checked that, along the lines of the analysis with the $(1-\alpha)$-variant, $\frac{\partial t^\star}{\partial \underline{m}}|_{d\Delta m=0} < 0$ and $\frac{\partial R^\star}{\partial \underline{m}}|_{d\Delta m=0} < 0$. Therefore, our Proposition 3 from above still holds. However, and this is the main difference, policy instruments and therefore also net revenues are now independent of student mobility in equilibrium.

5 Conclusion

In this paper we presented a two-country-two-instrument fiscal competition model with two types of individual mobility: student and labor (i.e. graduate) mobility. The jurisdictions' governments have income taxes and higher education expenditures (in the form of an amenity to students if positive or tuition fees if negative) at their disposal for net revenue maximizing. Beside individual characteristics, captured by mobility costs in our model, countries' education and tax policies should have an impact on migration flows. Assuming a residence attachment to the location of education after graduating, students will not only take amenities/tuition fees but also income tax policy into account when deciding on studying in the country of origin vs. studying abroad. The reason is that a student a priori cannot be sure that he can leave the location of education after graduating from university (in order to escape from excessive income taxation) due to social networks and/or family ties established during his years of study. Therefore, both income taxes and education expenditures should be considered at the same time when dealing with internationally mobile students and high-skilled workers in a fiscal competition context. Our model allows considering those aspects simultaneously and lays open the mechanisms at work in strategic interaction and the consequences of increasing mobility on governmental net revenues.

First of all, we showed that taxes among jurisdictions as well as public education expenditures among jurisdictions are strategic complements. This is in line with results from the empirical literature analyzing the fiscal interaction among regions, states or countries and proving that a jurisdiction's policy is influenced by neighbors' policy. Furthermore, while for increasing student mobility we find typically an intensified pressure on the government budget, our main result is that governmental net revenues not necessarily decrease in case of increasing labor mobility. In fact they even increase. This is mainly due to a tax revenue increasing effect caused by a reduction of the income elasticity of the number of students in the country. We demonstrated this result to be robust against alternative modelings of migration decisions.

Appendix

A The uniform distribution of migration costs

See that

$$\begin{aligned} \Pr\{m > z\} &= \int_z^{\overline{m}} f(m)dm \overset{\text{(uniform distr.)}}{=} \frac{\overline{m} - z}{\Delta m}, \\ \Pr\{m < z\} &= \frac{z - \underline{m}}{\Delta m}, \end{aligned}$$

with $z \in \{(t_i - t_j)w, (t_j - t_i)w, \frac{(t_i - t_j)w}{(1-\alpha)}, \frac{(t_j - t_i)w}{(1-\alpha)}\}$.

Furthermore,

$$\begin{aligned} \mathrm{E}\{m | m < (t_i - t_j)w\} &= \int_{\underline{m}}^{(t_i - t_j)w} \frac{1}{\Pr\{m < (t_i - t_j)w\}} m f(m) dm \\ &= \frac{\Delta m}{(t_i - t_j)w - \underline{m}} \int_{\underline{m}}^{(t_i - t_j)w} m \underbrace{f(m)}_{\frac{1}{\Delta m}} dm \\ &= \frac{1}{2}[(t_i - t_j)w + \underline{m}] \end{aligned}$$

and

$$\mathrm{E}\{m(1-\alpha) | m(1-\alpha) < (t_j - t_i)w\} = \frac{(1-\alpha)}{2}\left[\frac{(t_j - t_i)w}{(1-\alpha)} + \underline{m}\right].$$

B Calculations for the proof of Proposition 1

Remember that

$$\mathbf{H} \cdot \begin{bmatrix} \frac{\partial t_i}{\partial s_j} \\ \frac{\partial s_i}{\partial s_j} \end{bmatrix} = \begin{bmatrix} -\frac{\partial R^t}{\partial s_j} \\ -\frac{\partial R^s}{\partial s_j} \end{bmatrix} \quad \text{and} \quad \mathbf{H} \cdot \begin{bmatrix} \frac{\partial t_i}{\partial t_j} \\ \frac{\partial s_i}{\partial t_j} \end{bmatrix} = \begin{bmatrix} -\frac{\partial R^t}{\partial t_j} \\ -\frac{\partial R^s}{\partial t_j} \end{bmatrix}$$

with

$$\mathbf{H} = \begin{bmatrix} \frac{\partial R^t}{\partial t_i} & \frac{\partial R^t}{\partial s_i} \\ \frac{\partial R^s}{\partial t_i} & \frac{\partial R^s}{\partial s_i} \end{bmatrix}.$$

We want to derive $\det(\mathbf{H})$, $\det(\mathbf{H}_1^s)$, $\det(\mathbf{H}_2^s)$, $\det(\mathbf{H}_1^t)$ and $\det(\mathbf{H}_2^t)$, where

$$\mathbf{H}_1^s := \begin{bmatrix} -\frac{\partial R^t}{\partial s_j} & \frac{\partial R^t}{\partial s_i} \\ -\frac{\partial R^s}{\partial s_j} & \frac{\partial R^s}{\partial s_i} \end{bmatrix} \quad , \quad \mathbf{H}_2^s := \begin{bmatrix} \frac{\partial R^t}{\partial t_i} & -\frac{\partial R^t}{\partial s_j} \\ \frac{\partial R^s}{\partial t_i} & -\frac{\partial R^s}{\partial s_j} \end{bmatrix}$$

and

$$\mathbf{H}_1^t := \begin{bmatrix} -\frac{\partial R^t}{\partial t_j} & \frac{\partial R^t}{\partial s_i} \\ -\frac{\partial R^s}{\partial t_j} & \frac{\partial R^s}{\partial s_i} \end{bmatrix} \quad , \quad \mathbf{H}_2^t := \begin{bmatrix} \frac{\partial R^t}{\partial t_i} & -\frac{\partial R^t}{\partial t_j} \\ \frac{\partial R^s}{\partial t_i} & -\frac{\partial R^s}{\partial t_j} \end{bmatrix}.$$

See that

$$\begin{aligned}
\frac{\partial R^t}{\partial t_i} &= 2w\frac{\partial L_i}{\partial t_i} + t_i w \frac{\partial^2 L_i}{\partial t_i^2} \overset{\text{(equilibrium)}}{=} -2w\left[\frac{2(\overline{m}+\underline{m})^2 w}{\Delta m^2 \Delta m_0} + \frac{2w(\overline{m}_0 - \frac{\underline{m}_0}{(1-\alpha)} + \frac{\alpha A \underline{m}^2}{2\Delta m})}{\Delta m \Delta m_0}\right], \\
\frac{\partial R^t}{\partial s_i} &= \frac{4(\overline{m}+\underline{m})w}{\Delta m \Delta m_0} = -2\frac{\partial R^t}{\partial s_j}, \\
\frac{\partial R^t}{\partial t_j} &= w\frac{\partial L_i}{\partial t_j} + t_i w \frac{\partial^2 L_i}{\partial t_i \partial t_j} \overset{\text{(equilibrium)}}{=} w\left[\frac{2(\overline{m}+\underline{m})^2 w}{\Delta m^2 \Delta m_0} + \frac{2w(\overline{m}_0 - \frac{\underline{m}_0}{(1-\alpha)} + \frac{\alpha A \underline{m}^2}{2\Delta m})}{\Delta m \Delta m_0}\right], \\
\frac{\partial R^s}{\partial t_i} &= \frac{4(\overline{m}+\underline{m})w}{\Delta m \Delta m_0} = -2\frac{\partial R^s}{\partial t_j}, \\
\frac{\partial R^s}{\partial s_i} &= -\frac{4}{\Delta m_0} = -2\frac{\partial R^s}{\partial s_j}.
\end{aligned}$$

Using all this, we can calculate the (equilibrium) values of the Hessian determinants.

$$\begin{aligned}
\det(\mathbf{H}) &= \frac{\partial R^t}{\partial t_i}\frac{\partial R^s}{\partial s_i} - \frac{\partial R^s}{\partial t_i}\frac{\partial R^t}{\partial s_i} = \frac{16w^2}{\Delta m \Delta m_0^2}\left(\overline{m}_0 - \frac{\underline{m}_0}{(1-\alpha)} + \frac{\alpha A \underline{m}^2}{2\Delta m}\right), \\
\det(\mathbf{H}_1^s) &= -\frac{\partial R^t}{\partial s_j}\frac{\partial R^s}{\partial s_i} + \frac{\partial R^s}{\partial s_j}\frac{\partial R^t}{\partial s_i} = 0, \\
\det(\mathbf{H}_2^s) &= -\frac{\partial R^t}{\partial t_i}\frac{\partial R^s}{\partial s_j} + \frac{\partial R^s}{\partial t_i}\frac{\partial R^t}{\partial s_j} = \frac{8w^2}{\Delta m \Delta m_0^2}\left(\overline{m}_0 - \frac{\underline{m}_0}{(1-\alpha)} + \frac{\alpha A \underline{m}^2}{2\Delta m}\right), \\
\det(\mathbf{H}_1^t) &= -\frac{\partial R^t}{\partial t_j}\frac{\partial R^s}{\partial s_i} + \frac{\partial R^s}{\partial t_j}\frac{\partial R^t}{\partial s_i} = \frac{8w^2}{\Delta m \Delta m_0^2}\left(\overline{m}_0 - \frac{\underline{m}_0}{(1-\alpha)} + \frac{\alpha A \underline{m}^2}{2\Delta m}\right), \\
\det(\mathbf{H}_2^t) &= -\frac{\partial R^t}{\partial t_i}\frac{\partial R^s}{\partial t_j} + \frac{\partial R^s}{\partial t_i}\frac{\partial R^t}{\partial t_j} = 0.
\end{aligned}$$

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