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► **To cite this version:**

Gabrielle Demange, Robert Fenge, Silke Uebelmesser. Financing Higher Education in a Mobile World. Journal of Public Economic Theory, 2014, 16 (3), pp.343-371. 10.1111/jpet.12064 . halshs-00979116

HAL Id: halshs-00979116

<https://shs.hal.science/halshs-00979116>

Submitted on 26 Feb 2024

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CESIFO WORKING PAPER NO. 3849
CATEGORY 5: ECONOMICS OF EDUCATION
JUNE 2012

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Financing Higher Education in a Mobile World

Abstract

This paper analyzes how integrated labor markets affect the financing of higher education. For this, we employ a general-equilibrium model with overlapping generations and individuals who differ in their abilities. At the first stage, governments can choose the quality of education and the financing system. At the second stage, individuals make their education and migration decisions given the governmental framework for higher education and the mobility assumptions.

In a closed economy and in the presence of imperfect credit markets, a mix of tax- and fee-financing is optimal. In integrated labor markets, countries have an incentive to attract skilled workers and to free-ride on education provided by other countries. When only skilled workers are mobile, there is a sub-optimal shift from taxes to fees and the number of students is too low. When also students can migrate, there is a countervailing force such that maintaining the optimal financial mix becomes possible.

JEL-Code: I200, H700.

Keywords: higher education, labor migration, tuition fees, taxes.

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June 11, 2012

This paper is a substantially revised version of an earlier paper published as CESifo Working Paper 2362. Financial support of the Bavarian-French Centre of Cooperation (BFHZ-CCUFB) is gratefully acknowledged. We are also grateful for support by the WGL Leibniz Association within the project “How to Construct Europe”. We thank Bas Jacobs for helpful comments.

1 Introduction

There is a tendency in the financing of higher education to introduce or extend the part financed by tuition fees. Although tax-financing remains the major part in most industrialized countries, fee-financing has become more and more important. In Germany, tuition fees have been allowed by constitution since 2005. In the United Kingdom the maximum level of tuition fees has more than tripled in the last 12 years. This significant shift in the financing mix is the topic of this paper. We investigate the financing system of higher education against the background of increased mobility across country borders and educational systems. The purpose of this paper is to analyze how increasingly integrated labor markets affect the financing systems of higher education in the countries involved. Therefore, we study the transition from a closed economy with an isolated labor market to open economies where skilled workers and students can freely migrate. This reflects the development within the European Union.

More precisely, we look at a two-period general-equilibrium model with two ex-ante identical countries. Individuals differ in their innate abilities, which are not observable. Furthermore, credit markets may be distorted which affects the individual possibility to finance higher education by student's loans. At the first stage, governments choose the educational policy. At the second stage, individuals make their education and migration decisions given the governmental framework for higher education and the specific mobility assumptions.

In the first part, we consider a closed economy. It turns out that the optimum in terms of the quality level of and the access restrictions to higher education can be achieved with a well chosen mix of fee- and tax-financing, even though abilities are not observable and credit markets are imperfect. The reason for partial tax-financing is to incite more individuals to opt for universities by subsidizing higher education. Otherwise, the number of students would be too low due to credit market restrictions.

In the second part, we analyze open economies. In integrated labor markets, countries have an incentive to attract skilled workers and to free-ride on education provided by other countries. As migration of different groups can be expected to have different effects, we study two migration scenarios - one where only skilled workers are mobile and one where, in addition, also students can freely migrate (see, e.g., Demange, Fenge and Uebelmesser, 2008a, for a discussion of the empirical evidence). When only skilled workers are mobile, there is indeed a sub-optimal shift from taxes to fees and the number of students is too low. When also students can migrate, there is a countervailing force such that maintaining the optimal financial mix becomes possible.

The contribution of our paper is two-fold: First, it complements the literature on the public provision of higher education by a general-equilibrium analysis of the financing structure, i.e. the tax-fee mix. In an open-economy context, the literature has largely studied competition via the quality of education or the financing when education is tax-financed. Justman and Thisse (1997, 2000), Mechtenberg and Strausz (2008) and Kemnitz (2010) are examples of papers which focus on the quality level, while Thum and Uebelmesser (2003) and Poutvaara (2004, 2008) study the structure, i.e. the relative importance of internationally and domestically applicable contents of higher education. Other papers analyze the financing-side of educational policy in the presence of fiscal competition. In the general-equilibrium setting of Wildasin (2000), e.g., tax level and tax structure are the choice variables while the simultaneous competition in the tax rate and a further fiscal instrument is central in Andersson and Konrad (2003), Haupt and Janeba (2009) and Krieger and Lange (2010). The financing mix of higher education -even though of high political relevance- has not been in the center of this previous work.¹ Our approach differs in that we focus on governmental decisions about the financing regime.

¹An exception is the analysis in Kemnitz (2010), where special attention is given to the question as to what extent fees crowd out public funds albeit in the framework of a federation.

Furthermore, we use a general-equilibrium approach where individuals are heterogeneous with respect to their abilities. We thus not only analyze the decisions where to study -at home or abroad- and where to work but, contrary to much of the literature, also the preceding decision of whether to study at all is endogenously determined as a function of individual ability taking the financial regime and the quality level of education into account. So, this general-equilibrium setting allows us to highlight the impact of a changed financial regime on the number of students and to provide policy advice for governments which contemplate changing the tax-fee mix. In addition, as a side benefit, the robustness of the under- or overprovision results derived in the literature in partial-equilibrium frameworks can be assessed.

In the next section, we present the model. In Section 3, we analyze the education decision in a closed-economy setting before considering education and migration decisions when economies are open in Section 4. Section 5 concludes. Most proofs are gathered in Section 6.

2 The Model

We study a two-stage game with two countries. For this, we employ an intertemporal general-equilibrium model with overlapping generations where each generation lives for two periods. At the first stage, governments can choose the quality of education and the financing system. At the second stage, individuals make their education and migration decisions given the education policy in place and the mobility scenario.

In more detail, in the first period, individuals decide about acquiring higher education which affects labor supply in the second period. In particular, individuals decide whether and where to study. For this, they compare the lifetime income with higher education to the lifetime income when uneducated. If individuals choose not to study, they work and receive the wage income of an unskilled worker in both periods in their home country. If individuals decide to acquire higher education at home or abroad, they receive no wage income in the first period. In the second period, if they are mobile, they decide in which country to work and earn the wage income of a skilled there. Taxes and/or fees are paid according to the financial regime in place. We assume that the population is constant, and concentrate on steady state situations. We specify now the production, education and financing settings.

Production Sector There is a single good, which is produced in each country. The good is not storable, hence there is no capital.² There are two kinds of input: labor supplied by individuals with and without higher education, L_s (skilled labor) and L_u (unskilled labor), respectively. Production takes place according to a neoclassical production function with constant returns to scale so that

$$F(L_u, L_s) = L_u f\left(\frac{L_s}{L_u}\right) = L_u f(l) \tag{1}$$

where $l = \frac{L_s}{L_u}$ denotes the ratio of skilled to unskilled labor and $f'(\cdot) > 0$, $f''(\cdot) < 0$. We assume competitive labor markets in each country. The optimal demand for labor implies that productivities of skilled and unskilled workers are equal to their respective wage rates w_s and w_u

$$w_s = f_l \tag{2}$$

$$w_u = f - lf_l. \tag{3}$$

²We abstain here from explicitly considering capital in the production technology. Taking the effect of education on capital into account would be interesting, but it is outside the scope of the present paper.

It follows that

$$\frac{\partial w_u}{\partial L_s} > 0; \quad \frac{\partial w_s}{\partial L_s} < 0; \quad \frac{\partial w_u}{\partial L_u} < 0; \quad \frac{\partial w_s}{\partial L_u} > 0. \quad (4)$$

Throughout the paper, to avoid corner solutions, we shall assume Inada conditions, according to which marginal productivities with respect to a factor increase indefinitely as the factor becomes scarce:

Assumption 1: $\lim_{L_u \rightarrow 0} F_{L_u}(L_u, L_s) = \infty$ and $\lim_{L_s \rightarrow 0} F_{L_s}(L_u, L_s) = \infty$.

Apart from the technology-related interpersonal links, which are reflected in the complementarity between skilled and unskilled workers, we do not consider any additional externalities.

Education Individuals are distinguished by an ability parameter, y , which reflects individually different benefits from higher education. The distribution of abilities is identical in each country and assumed for simplicity to be uniform in the range $[0, \bar{y}]$. For unskilled jobs, the ability level is not relevant. The ability level becomes important, however, as the returns of higher education are concerned. To be skilled, an individual must receive higher education where educational quality or the educational level, respectively, is denoted by e , $e > 0$. Both, the educational level e as well as the innate ability y , together generate the skill-units an individual is endowed with after having acquired education, which is the quantity of skilled labor provided by an educated worker: ye . It will turn out that only some individuals of a generation with high enough abilities decide to study while the rest starts working as unskilled.

For simplicity, we assume that the amount of money spent for higher education per individual only depends on the educational level, given by $c(e)$, i.e. the variable costs of education are proportional to the number of students, given the quality. The cost function c is assumed to be increasing and convex and the marginal costs of education to rise infinitely with its level, i.e. $\lim_{e \rightarrow \infty} c'(e) = \infty$.

Providing higher education, in addition, leads to costs which are fixed and therefore independent of the number of students. These costs will not be explicitly included in the following as the marginal analysis is not affected by them. Nevertheless, it is important to note that the fixed costs, and the resulting increasing returns to scale, imply a uniform, country-specific level of educational quality in the sense that -once decided by the social planner or the government- it applies to all students of a country. There are also institutional reasons for this assumption: On the one hand, this reflects the observed limited variability of the quality of educational programs within a country (at least relative to the variability across countries) -a relict of the long-time goal of many European countries to have a rather uniform quality level for equity reasons. To say it differently, there is a number of educational levels, which is smaller than the number of individuals. Considering one educational level hence presents the limiting case. On the other hand, this also means that the publicly provided educational quality cannot be topped up privately, which approximately captures the situation in most EU-countries where higher education is predominantly publicly financed (see OECD, 2011).

Credit Market We distinguish between perfect and imperfect credit markets. As shown by Gale (1973), in a dynamic model without capital as we have it here, feasible states are characterized by the condition that interest payments are zero. There are two possible steady states: either the equilibrium interest rate is equal to the population growth rate and there is borrowing between different generations (the golden rule equilibrium) or there is no borrowing between different generations and the interest rate will be different from the population growth rate (the autarky or no-trade equilibrium).

We rule out autarky and focus instead on the golden rule interest rate as the young who want to study have to borrow to finance the tuition fees (if any) since they have no earnings in the first period. In the absence of any frictions, this interest rate is here zero because the population is assumed to be constant. The intuition for this result is as follows: As we will see, in our model, income is scarcer when young and more abundant when old -at least for those who do not earn any wage income while studying in the first period. If higher education is (partially) fee-financed, there is a credit demand by the young who want to study and a credit supply by the old who have studied and now enjoy higher wages for qualified work. There might also be borrowing from the unqualified young and old, but for the sake of the clarity of the argument we abstract from this here. As society consists of a mix of young and old individuals at any point in time, demand and supply are rather balanced -at least for the case that the two groups, the potential borrowers and the potential lenders, are of equal size. This follows here as the population growth rate is zero. Financial institutions, if any, are then pure intermediaries.

When credit markets are not perfectly competitive, however, the interest rate is positive and the interest payments accrue to the financial intermediaries. These payments present a deadweight loss. Another interpretation of a positive interest rate is that there are moral hazard problems (see von Weizsäcker and Wigger, 2001, and Jacobs and van der Ploeg, 2006). A risk premium is then charged by credit markets due to the risky investment in human capital.

In the following we will analyze how this imperfection affects the optimal financing of higher education compared to a situation where credit markets are perfect.

3 Education Decision in Closed Economies

As a benchmark, this section disregards migration effects and analyzes the individual and governmental decisions within a closed country.

3.1 Individual Decision

We start with the second stage of the game. Hence, we analyze the individual choice of studying and the resulting equilibrium on the labor market.

We present here a mixed-system where higher education is financed partly by fees paid by students and partly by taxes levied on labor income as the most general case. The tax bears on all wage income in a given period, and we assume that there is no distortionary impact of taxes on the labor-leisure choice.

More specifically, a student pays a fraction $0 \leq f \leq 1$ of the education costs as fees during the first period, $fc(e)$, and earns no wage income. In the second period, the educated worker with ability y receives a wage income net of tax of $(1 - \tau)w_sye$ where τ is the tax rate levied to finance the remaining costs of higher education.

Thus the lifetime income -appropriately discounted by r - is

$$(1 - \tau) w_s \frac{ye}{1 + r} - fc(e). \quad (5)$$

If the individual decides not to study she receives a wage income net of tax of $(1 - \tau)w_u$ in both periods. Hence, the lifetime income is

$$(1 - \tau) w_u \frac{2 + r}{1 + r}. \quad (6)$$

The individual compares the lifetime incomes and chooses the option that maximizes the income. The decision whether to study or not depends on the ability of the individual. The marginal

ability type who is indifferent between both options can be characterized by

$$y^{FT} = \frac{w_u(2+r)}{w_s e} + \frac{(1+r)f c(e)}{(1-\tau)w_s e}. \quad (7)$$

Of course, the pure fee-system and the pure tax-system are obtained as special cases. With obvious notation, taking respectively $(\tau = 0; f = 1)$ and $(f = 0; 0 < \tau < 1)$, we have

$$y^F = \frac{w_u(2+r) + (1+r)c(e)}{w_s e} \quad (8)$$

$$y^T = \frac{w_u(2+r)}{w_s e}. \quad (9)$$

In general, we find that -quite intuitively- the higher the share of education costs financed by taxes, the more attractive it is to become skilled. This allows escaping the tax duties during the first period when studying and above all this implies a reduced total financial burden as part of the costs are co-financed by the unskilled via their tax payments.

3.1.1 Equilibrium Employment

We are interested in the effect of the quality level on individual decisions and the resulting impact on the labor market. We describe here how a (steady-state) equilibrium of the labor market is determined by the financing parameters f , τ and r .

We focus here on an equilibrium under rational expectations. This means that the individual decisions to be skilled or unskilled just derived are based on 'expected' wages. These decisions, more precisely the ability threshold of the marginal individual, determine the supply of skilled and unskilled labor, which in turn determines the wages that clear the markets. At an equilibrium, these realized wages must be equal to the initial, expected wages.

Let us describe more precisely the labor market. As already mentioned, the population growth rate is assumed to be zero. In each period, employment consists of young and old unskilled workers and old skilled workers. Given the educational level e and the ability threshold y , the employment of unskilled labor is

$$L_u = 2 \int_0^y 1 dz = 2y = 2N_u \quad (10)$$

where N_u is the number of unskilled workers per generation and equal to y . The *effective* skilled labor is given by

$$\begin{aligned} L_s &= \int_y^{\bar{y}} z e dz = e \left(\frac{\bar{y}^2 - (y)^2}{2} \right) = (\bar{y} - y) e \left(\frac{\bar{y} + y}{2} \right) \\ &= N_s e \left(\frac{\bar{y} + y}{2} \right) \end{aligned} \quad (11)$$

where N_s is the number of skilled workers and equal to $\bar{y} - y$. Effective skilled labor is equal to the number of skilled workers multiplied by their average ability and the quality level.

The above expressions determine the labor forces and hence the wages of skilled and unskilled labor thanks to (2) and (3) as a function of the threshold y and the educational level e . We denote these wages by $w_s(y, e)$ and $w_u(y, e)$.

These wages in turn determine the incentives to be skilled, i.e. they determine y^{FT} as given by (7). At an equilibrium of the labor market, the obtained value y^{FT} must be equal to the initial value y , i.e. $y^{FT}(e)$ must solve

$$y - \frac{w_u(y, e)(2+r)}{ew_s(y, e)} - \frac{(1+r)fc(e)}{(1-\tau)ew_s(y, e)} = 0. \quad (12)$$

The next proposition states the existence and uniqueness of an equilibrium and analyzes in which direction changes in the financing variables affect the ability threshold at equilibrium (accounting for the equilibrium impact on wages) and hence skilled and unskilled labor.

Proposition 1 *Given (f, τ) , there is a unique equilibrium in the labor market, i.e. a unique threshold solution $y^{FT}(e)$ to (12). The ability threshold $y^{FT}(e)$ increases with f , τ and r .*

The proof is given in Section 6. Let us provide some intuition for the results.

As for uniqueness, observe that as there are fewer skilled individuals, the incentives to become skilled are enhanced through the impact on wages, which gives an equilibrating force. In other words, increasing the threshold ability means that fewer workers become skilled which raises the wage rate for skilled and decreases the wage rate for unskilled.

The effects of f , τ and r on the ability threshold are unambiguous. As to f , the intuition is clear. Assume by contradiction that as f increases, more individuals decide to study. Then, not only would the part of the education costs which is borne by students via fees be larger, but also the skilled wage would diminish and the unskilled wage would increase. All these effects would diminish the incentives to study, leading to the contradiction.

As the tax rate τ is increased, the argument is similar but more subtle because both skilled and unskilled labor is taxed. However, for someone who decides to study, in particular the marginal student, the total wage as skilled is surely larger than the total wage as unskilled so as to cover the cost of education. Hence the cost of increasing the tax rate is larger for those who decide to study than for the others, and the previous argument applies. Similarly, a larger r means that the returns to the education investment are discounted more heavily -or alternatively that the credit costs for the fee part are more important. This also reduces the number of individuals who acquire higher education.

3.2 Educational Policy

Now we analyze the first stage of the game. We first derive the optimal allocation in the absence of any informational constraints. Then, we compare it to the decisions of the government.

3.2.1 Optimal Allocation

Under complete information about individuals' abilities, a social planner can decide on the level of education and on the ability of those who study. The social planner is able to perform all the transfers between individuals alive in the same period subject to the feasibility constraint given by the available amount of resources in that period. At a stationary allocation, the amount of resources available per period is constant, given by aggregate production net of education costs, and the welfare of a generation only depends on this amount (see e.g. Gale 1973).

Thus, the social planner's objective is to maximize aggregate production net of education costs at a steady state

$$W(y, e) = F(L_s, L_u) - N_s c(e) \quad (13)$$

by choosing e and y , where L_s and L_u are functions of e and y from (10) and (11) and N_s is a function of y alone.

The objective is concave, and thanks to Assumption 1 (Inada condition), we face an interior optimum, denoted by (e^*, y^*) . At the optimum, the level of education and the threshold ability level are characterized by the first-order conditions.³ The impact of a marginal increase in e keeping the set of students fixed is given by

$$\begin{aligned}\frac{\partial W}{\partial e} &= F_{L_s} \frac{\partial L_s}{\partial e} + F_{L_u} \frac{\partial L_u}{\partial e} - N_s c'(e) \\ &= (\bar{y} - y) \left[w_s \frac{\bar{y} + y}{2} - c'(e) \right].\end{aligned}\tag{14}$$

It is equal to the effect of the quality level on the production of the skilled workers minus the increase in costs. The impact of a marginal increase in the minimum ability level y keeping the educational level fixed is given by

$$\begin{aligned}\frac{\partial W}{\partial y} &= F_{L_s} \frac{\partial L_s}{\partial y} + F_{L_u} \frac{\partial L_u}{\partial y} - c(e) \frac{\partial N_s}{\partial y} \\ &= -w_s e y + 2w_u + c(e).\end{aligned}\tag{15}$$

It is equal to the net impact on the productivity of a student of ability just equal to y from becoming skilled compared to remaining unskilled. Thus the optimal values for the level of education and the threshold ability level (e^*, y^*) are characterized by

$$(\bar{y} - y) \left[w_s \frac{\bar{y} + y}{2} - c'(e) \right] = 0\tag{16}$$

$$-w_s e y + 2w_u + c(e) = 0\tag{17}$$

The first condition determines the optimal educational quality given the level y : the marginal gain from a change in education on the average student is equal to the marginal costs. The second condition determines the optimal ability threshold given the educational level: the net gain of education for the marginal student is zero, i.e. the skilled wage in the second period net of the costs of education in the first period just equals the opportunity costs in form of unskilled wages in both periods measured at the steady state.

In the following analysis, individual abilities are no longer observable, which may generate distortions of the individual decisions to study, hence affect the government's policy choices. This leads us to consider different levels of education e , not necessarily the optimal one e^* , and to compare individual choices given e with the choice that an omniscient planner would take under perfect information on abilities.⁴

Definition 1 *Given an educational level e , the threshold $y^*(e)$ that maximizes welfare is called "e-optimal". It satisfies (17): $\frac{\partial W}{\partial y}(y, e) = 0$, or $-w_s(y, e)ey + 2w_u(y, e) + c(e) = 0$.*

At the optimal threshold level, the amounts of skilled and unskilled labor maximize production net of educational costs (for a given educational level). Of course, we have $y^* = y^*(e^*)$ (without much confusion on notation).

Without imperfect credit market, $r = 0$, individuals take the optimal decision when they pay the full cost of education, i.e. for $f = 1$ and $\tau = 0$. This can be seen by comparing the optimality condition (17) with the threshold expression (8) at $r = 0$. Since there are no externality effects in our model, individuals' choices are not distorted under full fee financing and perfect credit markets. The case of imperfect credit market will be studied next.

³If the costs are linear, one has to assume, in addition, that education levels are bounded: from (14) with $c'(e) = 1$, if the return to education is positive for y , then education should be as large as possible, i.e. the optimal level is at the upper bound.

⁴The alternative notion of an educational level optimal for a given y can be considered, but it is less meaningful in our setting where the educational level is observed but not ability.

3.2.2 Governmental Decision

Our aim is to compare the governmental decision with the optimal allocation. The government faces two constraints.

First, individual abilities are no longer observable (or contractible). Due to these informational asymmetries, the set of students can no longer be directly chosen by the government as an omniscient social planner does but it depends on the educational decisions of the individuals. The best the government can do is to set the level of education taking account of these decisions, which are determined by the ability threshold.

Second, the interest rate faced by the individuals is not at the golden rule level (equal to zero) but can now be positive following the arguments provided above (cf. Section 2).

With mixed financing, the costs of higher education are partly financed by tuition fees paid by the students and partly by taxes levied on wage income. The budget of the government is given by:

$$\tau(w_s L_s + 2w_u N_u) = (1 - f)c(e)N_s, \quad f \in [0, 1] \quad (18)$$

The government maximizes aggregate production net of education costs by choosing simultaneously the educational level e and the share of costs financed by fees, f :

$$\underset{e, f}{Max} W(y^{FT}(e), e) = F(L_s, L_u) - N_s c(e) \quad (19)$$

where the tax rate τ is endogenously determined by the budget constraint (18). Since $F(L_s, L_u) = w_s L_s + 2w_u N_u$, welfare is also equal to $[1 - \tau/(1 - f)]F(L_s, L_u)$ and we may restrict our analysis to $\tau < (1 - f)$. The threshold ability for studying is now given by (7). Skilled and unskilled labor levels are those determined by the equilibrium threshold ability level $y^{FT}(e)$,

$$N_s = \bar{y} - y^{FT}(e), L_u = 2y^{FT}(e), L_s = N_s e \left(\frac{\bar{y} + y^{FT}(e)}{2} \right). \quad (20)$$

Assume that, for historical reasons or as a result of institutional constraints, the educational level is fixed at some level, e , which is not necessarily the optimal level. We want to know if the government can achieve the optimal ability level for the skilled and unskilled labor forces through an appropriate mix-financing regime. For this, one must find f and τ for which individual incentives are such that the threshold equilibrium value $y^{FT}(e)$ is equal to the e -optimal ability threshold $y^*(e)$, and the budget constraint (18) is satisfied. We find the following result:

Proposition 2 *Consider an economy where taxes and tuition fees are available to finance higher education. Let the quality level of higher education, e , be given.*

1) *With a perfect credit market, $r = 0$, pure fee-financing is optimal and the e -optimal ability threshold, $y^*(e)$, is achieved.*

2) *With an imperfect credit market, $r > 0$,*

2a) *if distortions on the credit market are small, $r < \frac{c(e)}{w_u^*}$, there is a positive fee level, $f \in (0, 1)$, which allows achieving the e -optimal threshold, $y^*(e)$.*

2b) *if distortions on the credit market are high, $r > \frac{c(e)}{w_u^*}$, the e -optimal ability threshold $y^*(e)$ requires that education is subsidized, $f < 0$. A second-best solution is reached with a pure tax system, $f = 0$. In this case, the number of students is sub-optimally low.*

Applying the proposition to the optimal level, $e = e^*$, the following corollary obtains

Corollary 1 *If the optimal level e^* is chosen, the optimal allocation (e^*, y^*) can be reached through an appropriate financing-mix.*

The proof of Proposition 2 is given in Section 6. Let us briefly comment on this result. If the interest rate is at the golden rule level, the optimum for a given e is reached with pure fee-financing. This is intuitive as in the absence of any distortions, there is no reason for governmental intervention in the form of tax-financing of higher education. If, however, the interest rate exceeds the golden rule level due to distortions on the credit market, these distortions justify a (partial) intervention of the government via tax-financing. In fact, if the distortions increase, the number of students decreases. This follows from the fact that a high interest rate means that second-period wage income is heavily discounted. For some individuals, studying, where all earnings are realized in the second period, becomes less attractive than remaining unskilled (cf. Proposition 1). The optimal share of educational costs financed by tuition fees therefore has to decrease and the one financed by taxes has to increase to encourage more individuals to study. For very large distortions, i.e. $r > \frac{c(e)}{w_u^*}$, even negative tuition fees are needed. Beside indirect subsidization of higher education via the tax-system, as both skilled and unskilled workers contribute to the financing, there is, in addition, direct subsidization of those who decide to study. If this direct subsidization (negative tuition fees) is not possible, pure tax-financing allows for a second-best solution. The number of students is then, however, smaller than the optimum as the distortions are not fully compensated by the government via the financial regime.

Proposition 2 shows that the problems of determining the optimal educational level or the optimal number of students can be treated separately as long as the government disposes of the policy instrument of choosing the tax-fee mix. If the financing mix is given for the government, say by a constitutional ban on fee-financing of higher education, any choice of an optimal educational level affects simultaneously the threshold level of ability, which, in general, prevents the implementation of the optimum (e^*, y^*) .

Note that here and in the following, we do not consider any distributional aspects which might arise when the financing regime is changed. A higher share of fees, e.g., on the one hand, affects the ability threshold so that some previously skilled individuals now remain unskilled and, on the other hand, decreases the tax burden for all skilled and unskilled. We focus instead on total production net of education costs as the objective to be maximized (with some modifications for the open economy case) which implies that the tax base is maximized as well. This can be used for redistributive activities which are, however, not considered here.

It is important to point out that so far the government only has to consider the "internal" reaction to its policies via the individual education decision as reflected in the ability threshold. This will serve as starting point for the following where we allow for mobility of students and skilled worker and thus add the possibility of an "external" reaction to the analysis. The question is how the policy of one country changes taking the policy of the other country into account.

4 Education and Migration Decisions in Open Economies

We consider the case with two identical countries A and B .⁵ In both countries the credit market is imperfect and we make the plausible assumption that the distortion is not too high so that $\frac{c(e)}{w_u} > r > 0$. From the previous analysis we know that as long as the countries are closed a mix-financing regime can be chosen that achieves the e -optimal number of students (ability threshold), such that with identical countries we have $y^A(e) = y^B(e) = y^*(e)$ for any e and especially for the optimal educational level e^* . In the next step the countries open up and migration of students and skilled workers takes place. We study in which direction -if at all- the financing mix and the number of students will deviate from the optimal levels when governments take migration into account.

⁵A generalization to n countries is straightforward but would complicate unnecessarily the notation.

In the following, we first present the impact of mobility on individuals' and governments' objectives on which the analysis is based. We then analyze the equilibrium policies when only skilled workers are mobile and discuss some implications when also students are mobile.

4.1 Individuals' and Governments' Objective under Mobility

4.1.1 Individuals

Unskilled individuals are assumed to be always immobile.⁶

If skilled workers are mobile, in the second period, they migrate between both countries as long as the net-of-tax wage income is different. Thus the migration equilibrium requires that skilled workers receive the same net wage income in both countries yielding the arbitrage condition⁷

$$w_s^A (1 - \tau^A) = w_s^B (1 - \tau^B). \quad (21)$$

Let us denote by a superscript the variables in country $i = A, B$. y^i then indicates the threshold level above which young agents study in country i . This threshold determines unskilled labor, L_u^i , the number of students, N_s^i , and the native skilled labor force, which is made up by native graduates, L_s^i , as follows

$$L_u^i = 2y^i, N_s^i = \bar{y} - y^i, L_s^i = e^i \left(\frac{\bar{y}^2 - (y^i)^2}{2} \right), \quad i = A, B. \quad (22)$$

The total skilled labor force in a country comprises native graduates and skilled migrants, the number of which can be positive or negative. Labor supplied by migrating skilled workers (in effective units) is by convention counted from country B to country A and denoted by m , $m \gtrless 0$. Thus, the total skilled labor force (in effective units) in country A amounts to $L_s^A + m$ while the skilled labor force in country B is given by $L_s^B - m$.

When mobile students are considered, in the first period, individuals not only have to decide whether to study but also where to study. We assume that there are no costs concerning the transferability of skills and the recognition of foreign qualification when taking up higher education abroad.⁸ Young individuals then compare their net lifetime income for all possible education and migration choices. This determines the marginal ability types of the young individuals who are indifferent between studying or not and migrating or not. For the decision where to study (if they study), individuals consider the difference

$$[(1 - \tau^A)e^A w_s^A y - (1 + r) f^A c(e^A)] - [(1 - \tau^B)e^B w_s^B y - (1 + r) f^B c(e^B)]. \quad (23)$$

A y -student for which this difference is positive (negative) studies in A (in B) if he or she studies at all. The migrating students are by convention counted from country A to country B .

⁶The fact that unskilled workers are considered to be immobile while students and skilled workers may migrate corresponds to empirical evidence according to which mobility increases with education. This has been shown for inner-country migration, e.g., by Ehrenberg and Smith (1994) for the United States, by Mauro and Spilimbergo (1999) for Spain, and by Hunt (2006) for Germany (see also Demange, Fenge and Uebelmesser, 2008a, for a discussion of the empirical evidence).

In addition, we allow for some non-perfect link between student and graduate mobility even without explicitly modeling it following, e.g., Dreher and Poutvaara (2011) and Parey and Waldinger (2011).

⁷We rule out corner solutions where all skilled individuals move to the same country by assuming that the Inada condition holds for the production function (cf. Assumption 1 above).

⁸When EU rules of non-discrimination apply, e.g., students do not face any mobility restrictions and have access to the educational system of a foreign country at the same conditions as natives.

For the decision whether to study, the young individuals then compare their net lifetime income when studying and working as a skilled worker with that of an unskilled worker. Since unskilled workers remain immobile, their income depends on the home country and equals $(1 - \tau^A)w_u^A(2 + r)$ or $(1 - \tau^B)w_u^B(2 + r)$, respectively.

Expression (23) is linear in y , which gives rise to three possibilities: either (a) individuals are all indifferent between studying in A or in B or (b) they split according to a threshold ability, or (c) they all prefer to study in the same country. Case (a) holds when the slopes and the intercepts are equal. By the arbitrage condition (21), the net skilled wages are equalized, hence it holds if (and only if)

$$e^A = e^B, f^A = f^B. \quad (24)$$

4.1.2 Governments' Objective

We choose here as objective the sum of the lifetime incomes of all workers who work in a country, the so-called 'residence principle'. This captures the case where a government is interested in attracting skilled workers who increase domestic production and deter students who generate costs. As students are concerned, it is reasonable to assume that a government does not care much for those who study abroad and generate costs there (no matter whether they are natives by birth or not). As to foreign skilled workers, they contribute to a larger domestic product which also means that the tax base is larger. This base can be used for educational expenditures (with at least partial tax-financing) or, which is not included in the model, for other public goods' expenditures when additional taxes are levied.⁹

We thoroughly considered other versions of objective functions including one where the objective is to maximize aggregate production of the native residents net of their education costs plus immigrants' tax payments. Different to the pure residence principle, the (marginal) product of migrants would not be taken into account by the destination country as one could argue that it is this which migrants take with them as earnings (net of taxes if any). Of course, migrants are then only valuable for the destination country because of their tax-payments. But with this objective function, the marginal product of migrant workers would not be included in any country's objective. So, we opted for the residence principle as the more standard way of capturing the governmental objectives.

We take the perspective of country A . Without imperfection on the credit markets, the sum of the lifetime income of all workers in A is

$$W^A = F^A(L_s^A + m, L_u^A) - N_{AA}c(e^A) - (1 - f^A)N_{AB}c(e^A) - f^B N_{BA}c(e^B) \quad (25)$$

where F^A is the value of production in A and N_{IJ} is the number of skilled individuals who study in I and work in J . The objective is the value of production in the country less the cost of education supported directly or indirectly by the workers in A : $N_{AA}c(e^A)$ is the cost of education of skilled workers who studied in A and stayed there, $(1 - f^A)N_{AB}c(e^A)$ represents the part of the cost which is supported by the workers in A (financed through taxes) for educating those who migrate to B , and $f^B N_{BA}c(e^B)$ is the part of the cost paid by the workers in A (through fees) who have studied abroad (the remaining part being paid by the tax-payers of

⁹A peculiar feature of the residence principle, which we are aware of, is the fact that welfare increases with the number of (native and non-native) residents. More precisely, this is the case as long as the additional product by migrants exceeds any possible (general-equilibrium) loss of resident natives because only the total product is taken into account and not the average or per capita product. This principle thus gives rise to the so called repugnant conclusion as population size can always be used as a substitute for quality of life (Parfit, 1982, and Blackorby, Bossert and Donaldson, 2009). For a more general discussion of the importance of the governmental objective function, see Mansoorian and Myers (1997) and Cremer and Pestieau (2004) among others.

country B). Using the government budget equation

$$(1 - f^A)[N_{AA} + N_{AB}]c(e^A) = \tau^A F^A \quad (26)$$

the objective can also be written as

$$W^A = F^A - [\tau^A F_A + f^A N_{AA}c(e^A) + f^B N_{BA}c(e^B)]. \quad (27)$$

It is obvious that for the case where only skilled workers are mobile, (25) reduces to

$$W^A = F^A(L_s^A + m, L_u^A) - N_{AA}c(e^A) \quad (28)$$

as $N_{AB} = 0$ and $N_{BA} = 0$.

4.2 Equilibrium Policies

We analyze the equilibrium policies which emerge when governments act on the basis of the objectives just described. We are especially interested in the impact on efficiency, i.e. the effect of mobility on deviations from the optimal threshold ability $y^*(e)$. For this, we study in detail how governments' decisions on the financial regime are affected by mobility when the level of education is arbitrarily fixed but the same due to identical countries, $e^A = e^B = e$.

For an interior equilibrium in open economy to exist, the governments must have no incentive to change the financing-mix (any further). Generally, two reactions to any policy change have to be taken into account so that a change in welfare can be decomposed into two parts: the first induced by a marginal change in y^A , dy^A , as if the economy was closed (internal reaction), and the second due to a change in migration of skilled workers and students (external reaction).

Let us analyze the equilibria by proceeding in two steps: we first study the internal reaction and then add the external reaction.

As to the internal reaction, increasing fees affects the studying decision as it discourages some individuals to study. Without equilibrium effects this is obvious: an increase in fees eases the budget because the spending per student is reduced and fewer individuals want to study. There are, however, two countervailing effects: the ratio of the skilled wage to the unskilled one increases and the tax decreases, both of which incite more people to study. But these effects do not offset the first one, so that higher fees result in a lower tax rate and fewer skilled workers, and finally in higher net skilled wages, as stated in the following proposition (see the proof in the Appendix).

Proposition 3 *When considering the internal reaction only, increasing fees leads to higher net skilled wages.*

As to the external reaction, we analyze first the situation where only skilled workers are mobile and complement the analysis by considering mobility of both students and skilled workers.

4.2.1 Only Skilled Workers are Mobile

We start from the e -optimal financing-mix of a closed economy. Now the borders open up and skilled workers can migrate. The governments contemplate increasing the fee level with the educational quality kept unchanged. With mobile skilled workers, the objective function of a country, say A , is given by (28), which is evaluated at the new migration equilibrium induced by the new value for the fee, as we now describe.

The fee is the strategic variable and other variables, individual behavior and tax levels, adjust to form an equilibrium. The equilibrium is determined by values for the thresholds, the

taxes and the migration level that satisfy equation (7) and balance the budgets according to (18) in the two countries and make the arbitrage condition (21) hold, up to a maximal tax level that we explain now. A change in a country may induce a change in the tax rate of the other country. To avoid unreasonable levels, we assume that there is a maximal tax level τ^{max} strictly smaller than 1 beyond which a country changes its policy tools and starts rationing the number of students.

Following a marginal change of the fee level, the equilibrium on the labor market is smoothly changed under a stability condition described below. Skilled workers decide whether to migrate or not by comparing the net skilled wages in both countries until wages are equalized.¹⁰ This allows us to focus on a marginal analysis. A marginal change in welfare due to a marginal change of the fee level can be decomposed into an internal reaction, dy^A , as analyzed in the previous section, and an external reaction, dm . We are thus ultimately interested in

$$\begin{aligned} \frac{\partial W^A}{\partial f^A} &= \frac{\partial (F(L_s^A + m, L_u^A) - N_s^A c(e^A))}{\partial f^A} = \\ &= [-w_s^A e^A y^A + 2w_u^A + c(e^A)] \frac{\partial y^A}{\partial f^A} + w_s^A \frac{\partial m}{\partial f^A} \end{aligned} \quad (29)$$

At the e -optimal financial-mix, the term in brackets is zero: the impact of a policy change within a country is null at the margin. Hence, the objective increases if $dm > 0$, i.e. if migration from B to A increases, and is decreased otherwise.

Thus, to assess whether a country has an incentive to increase its fee, we need to derive the direction of migration. For that, we introduce a stability condition. Consider a country with a given mix-financing policy. We consider the equilibrium net skilled wage in the country as if it is closed but experiences an extra exogenous amount m of skilled labor (which can be positive or negative) keeping the fee level fixed. The impact of migration on the net skilled wage of say a positive migration in a country is threefold: through the exogenous increase in skilled labor, through the impact on the ability thresholds due to the change in equilibrium wages, and through the impact on taxes to balance the budget (assuming this is possible) or through a rationing if the maximal tax level is reached. To simplify, the following discussion assumes away the latter case.

To emphasize the various dependencies, let us write the net skilled wage in country x , $x = A, B$, as

$$w_s^x(L_s^x + m, L_u^x)(1 - \tau^x(L_s^x + m, L_u^x)), \quad (30)$$

where w_s^x , L_s^x and L_u^x , and τ^x are the equilibrium levels when the country experiences the extra amount m of skilled labor (which can be positive or negative).

A difficulty is that net skilled wages might not be monotone in m accounting for equilibrium effects. Consider migration towards A for instance. An exogenous increase in skilled labor induces a decrease in the skilled wage and a decrease in the tax level because there are more taxpayers without additional cost. It can be shown that this creates a disincentive to acquire education: fewer people become educated, thereby allowing the government to decrease the tax even further.¹¹ Because of these two opposite effects, the net skilled wage in A may decrease or increase. This does not occur when tax effects are not predominant relative to wage adjustments.¹² This is described by the following stability condition: the net skilled wage in a country decreases with the inflow m .

¹⁰Note that thanks to Assumption 1 (Inada condition), not all skilled workers move to one country as a reaction to a marginal change of the fee level.

¹¹Decreasing the number of skilled lowers the cost of education by $fc(e)dN$ and the tax revenues by τdF . The former effect outweighs the latter so that a surplus is generated: the tax rate decreases.

¹²To understand better the stability condition and the importance of the maximal tax level, consider the simple

Proposition 4 *Let the educational level $e^A = e^B = e$ be given. Under the above stability condition, if only skilled workers are mobile, both countries have an incentive to increase fee-financing above the level which leads to the optimal ability threshold, i.e. the number of students is lower than optimal.*

The proof is given in the appendix. Here is a sketch of the proof. Remember first what happens if A increases its fee in a closed economy. As stated in Proposition 3, the net skilled wage in A increases and becomes larger than in B . Thus if the economies open, due to the difference in net skilled wages, all skilled workers would like to migrate from B to A . Increase the amount of migration gradually. Thanks to the stability condition the gap between the net skilled wages is decreasing with all levels of m , and eventually a level is reached that equalizes the net skilled wage or country B reaches its maximal tax level and stops educating students who want to become skilled so as to migrate to country A . Whatever situation, country A attracts some skilled workers for free and benefits from its move.

Without the stability condition, we cannot exclude that several level of migrations could be compatible with the change of fees by A . In that case it is unclear that the country surely benefits from its move.

We do not characterize Nash equilibria. Presumably, there is a symmetric equilibrium with fees larger than the optimal levels, possibly the maximal fee without any tax financing but not necessarily. Indeed as the fees increase, there is an internal cost (as the number of unskilled rises) to increase fees further which may outweigh the incentives to free-ride on the education provided by the other country. Whatever situation, at a symmetric equilibrium, welfare deteriorates due to the opening of the economies. However this is because we have assumed that the optimal financing-mix was in place in each country initially. If instead a tax system is in place and the optimal financing-mix entails some fees (i.e. distortions on the credit market are not too large) welfare can possibly be improved relative to the initial situation. Even if the fee ends up too large at a Nash equilibrium, the loss may be less than the benefit from increasing the fee. Such analysis of course relies on the fact that the initial situation is sub-optimal. In that perspective, opening the economy may trigger beneficial competition.

According to Proposition 4, increasing the fee level helps country A to attract skilled workers and to compensate for the lower number of native students free-riding on education provided by country B . The deviation from the optimal financing policy has been established in a framework with skilled workers as the only mobile group. One possibility to counteract this exclusive focus on this one group is to increase the mobility of other groups as well.

4.2.2 Skilled workers and students are mobile

We start again from the symmetric financing-mix which yields the e -optimal ability threshold in a closed economy. When also students can move freely, the external reaction changes. Mobile students compare the conditions to study in both countries. Let a country, say A , contemplate increasing its fee without changing the quality level of education. This reduces the attractivity of this country as a place to study compared to country B with a smaller fee. As can be seen from (23), the costs of acquiring education which have to be borne by the students increase in A

case of a linear technology (although it does not satisfy the Inada condition, it provides useful insight). The skilled wage is fixed and all the effects are channeled through the tax levels. In particular the arbitrage condition requires tax levels to be equalized. When country A increases its fee, thereby followed by a decrease in τ^A , all skilled workers of B move to A . Since there is no possible adjustment through wages, the tax level in B is increasing in the amount of skilled workers moving to A (thus decreasing in m with our sign convention) so as to satisfy the budget constraint. Furthermore, the tax level surely reaches its maximum. This case is extreme and furthermore does not satisfy the Inada assumption. However it illustrates the importance of the relative adjustments through changes in taxes and wages.

while the returns of this investment are unaffected as skilled wages are equalized in equilibrium (arbitrage condition (21)). It follows that all individuals will study in country B if they decide to study (cf. case c) as described in Section 4.1.1), and the costs of education in country A fall to zero. It is evident that these changes are far from being marginal. We, therefore, can no longer argue as previously by looking at small deviations. Furthermore, B may be unable to educate all these students without increasing its fee. We investigate these points in turn.

Consider welfare. At the initial situation, welfare is equal to (cf. (27))

$$W = F^* - N_s c(e) = (1 - \tau^*)F^* - f^*(N_{AA} + N_{BA})c(e) \quad (31)$$

where all variables denoted by a star, $*$, are the values in the initial optimum. After the change in fees, since there are no students in A , and $f^B = f^*$, welfare in country A is given by

$$W^A = F^A - f^* N_{BA} c(e) \quad (32)$$

where F^A is the production level associated to the new allocation of workers in the two economies. All skilled workers in A study abroad, hence their number is N_{BA} . Comparing this with the initial expression (31), it is as if the cost of education in A per student was reduced to $f^* c(e)$ or alternatively as if the tax could be set to zero and still satisfy budget balance.

As a result of the large inflow of students, country B has to drastically change its financing policy. It has to increase its tax rate, or to increase its fees if the maximum admissible tax level is reached. We discuss both cases.

When the system is mostly financed by taxes, it is likely it cannot absorb the additional costs of education by a sole increase in taxes. Thus, country B would have to increase fees up to the same level as in country A . This would lead back to the same financing policy with the same number of students in both countries. Higher education, however, would now be financed by a sub-optimal mix of fees and taxes leading to a sub-optimal number of students. Anticipating the reaction of country B , country A should abstain from increasing the level of fees in the first place. A symmetric situation would then result where the optimal finance mix of the closed economy can be sustained.

In the opposite case where the educational system is mostly financed by fees, we cannot exclude that country B is able to educate the inflow of students because the taxes are small anyway (To understand better this point, consider the extreme case of a pure fee system. Where students study has no impact at all on government budgets nor on welfare.) Country A is likely to benefit from its deviation: the production would possibly decrease a little bit but the cost of education would drop. We argue here, however, that it is unlikely that B does not react by increasing its fee as well.

First observe that by the arbitrage condition and the fact that the tax rate in A is null, the skilled wage in A is smaller than in B . Hence, by the homogeneity of the production function, the ratio of skilled labor to unskilled labor and the unskilled wage are larger in A than in B . This gives the following inequalities:

$$w_s^A < w_s^B, w_u^A > w_u^B, \text{ and } \frac{L_s^A}{L_u^A} > \frac{L_s^B}{L_u^B}.$$

It follows that the net unskilled wage income in A is surely larger than in B : $w_u^A > (1 - \tau^B)w_u^B$. As a result, natives in A have less incentive to study, and since unskilled do not move, we have $L_u^A > L_u^B$. But then the ratio of skilled to unskilled labor can be larger in A than in B only if there is migration of skilled workers born in B that is sufficiently massive. This is not very plausible. We thus consider the case where B reacts as well by increasing its fee as more realistic.

With two symmetric countries and two symmetric policies, there is no migration in equilibrium. If the countries anticipate this, they do not consider any effects resulting from an external reaction, only effects from the internal reaction. We can thus refer back to the analysis of the closed economy for any fixed quality level of education (cf. Proposition 2).

4.2.3 Discussion

So far we have analyzed the effects of mobility on the financing-mix for any given level of educational quality. However, if the financing-mix is not at the disposal of the government (e.g. due to a constitutional ban of fee-financing), the government might resort to the educational level as policy instrument. We briefly comment on the literature which focuses on the quality level in partial-equilibrium settings in order to then compare the results derived there with our results.

Mobility of skilled workers affects the public budget via a negative impact on the tax-base which typically leads to underprovision of education as a means to adjust public expenditures (see, Justman and Thisse 1997, 2000, as examples) or which leads to education with an inefficiently low level of internationally applicable skills (Poutvaara, 2004, 2008). Student mobility has similar consequences for the public provision of education as long as (most) students who study abroad return to their home country after graduation. Governments then fear free-riding and the negative effect on education expenditures (see, e.g., Del Rey, 2001, and Mechtenberg and Strausz, 2008).

Allowing for mobility of both, students and skilled workers at the same time, Lange (2009) has shown that mobile students work as a counterforce which sets incentives to increase the educational level again. In his framework, the stay rates of students and of post-graduate skilled workers are important and over- and underinvestment in education is possible.

Our paper complements the literature with an analysis with respect to the number of students. In the case of mobile skilled workers and with a given quality level of education, a sub-optimal financial-mix results which leads to a sub-optimal number of students. In this sense, education is also underprovided. With mobile students in addition, however, the optimal financing regime and hence the optimal number of students can be restored. Furthermore, we can directly reproduce the underprovision result of educational quality (see Demange, Fenge and Uebelmesser, 2008b, for the proofs) in our framework where the general-equilibrium effects are taken into account. This was not so clear at the outset. The beneficial (fiscal) effects of a lower educational quality via the smaller public budget for higher education and the resulting increased attractiveness of the country for skilled workers (and tax-payers) have to be weighed against the negative effect. This negative effect arises when the number of unskilled is too large, i.e. when too many individuals decide against studying given the chosen educational level. Hence, our approach delivers a robustness check of the underprovision result of the literature in a general equilibrium framework where the individual decisions to study are endogenous.

5 Conclusion

This paper is the first to thoroughly analyze the financing structure of higher education, i.e. the tax-fee mix, in countries which are part of an integrated labor market. In a general-equilibrium model, which takes account of the endogenous decisions of individuals to study or not, it is shown that a mixed regime leads to the optimal number of students in a closed economy. The tax-fee mix, i.e. the importance of taxes relative to fees, is a function of the capital market imperfections. This framework allows us to analyze also the effects of mobility on the number of students. We find that mobile skilled workers induce the countries to finance higher education by too high tuition fees (and too low taxes) which result in a too low number of students

compared to the closed-economy optimum. If the mobility of skilled workers (or graduates) is complemented by mobile students, countries may opt to maintain the financing-mix of a closed economy with the optimal number of students.

How do different developments affect the results? If capital markets become more efficient, the argument in favor of taxes becomes less important. This is the case, e.g., if the market for student loans gets more mature and risk premia fall. With the optimal tax-fee mix tilted more towards fees, the absolute deviation from the optimum becomes smaller when we consider the too high level of fees chosen by the countries with mobile skilled workers. Similarly, if the mobility of students sufficiently increases -e.g. as a result of the Bologna process, the implemented financial regime is less distorted.

We have restricted our analysis to symmetric countries which determine the education policy and raise the necessary financial resources. This framework deserves some discussion.

It is evident that countries in the European Union differ as their attractivity for foreign students and/or foreign graduates is concerned. The small countries Austria and Belgium, e.g., complain about the significant net inflow of students -mostly from their big neighbors Germany and France. The question is whether these asymmetric flows of migrants constitute an equilibrium or whether they must be interpreted as a transitional phase from one -closed economy- equilibrium to one -open economy- equilibrium. As long as it is not the case that some countries possess a more efficient production technology for education or other inherent advantages in relevant areas, there is no strong case to believe that these observed asymmetries will persist permanently within a rather homogeneous area as the European Union.

If we nevertheless allow for asymmetric countries and an asymmetric equilibrium exists, the differentiation of the financing structures and the quality levels could present one possibility to alleviate a sub-optimality inherent in our model. By assuming a uniform level of educational quality which applies to all students in a country, we have ruled out that education can be chosen such that it corresponds best to individual ability. If migration and the ensuing competition between countries result in differentiated quality levels across asymmetric countries, the uniformity of educational quality on a country-level is no longer so detrimental from a global welfare point of view. This is left for future research.

6 Mathematical Appendix

Proof of Proposition 1 We first show that there is a unique equilibrium on the labor market. An equilibrium threshold is implicitly given by (12). It is convenient to rewrite this equation by defining the net benefit for a y -agent to acquire education,

$$\Delta(y, e) = (1 - \tau)[ye w_s(y, e) - w_u(y, e)(2 + r)] - (1 + r) f c(e) \quad (33)$$

where $w_u(y, e)$ and $w_s(y, e)$ are the equilibrium wages if labor quantities are given by (10) and (11). With this notation, equation (12) writes as $\Delta(y, e) = 0$, which says that the net benefit of education is null for the marginal student.

Observe that the net benefit $\Delta(y, e)$ increases with y because increasing the threshold ability y means that fewer workers become skilled which raises the wage rate for skilled $w_s(y, e)$ and decreases the wage rate for unskilled $w_u(y, e)$. It follows that there is a solution y to $\Delta(y, e) = 0$, which furthermore is unique. First note that $\Delta(\cdot, e)$ changes sign when y runs over $]0, \bar{y}[$: thanks to the Inada conditions on productivities we have $\lim_{y \rightarrow 0} \Delta(y, e) < 0$ and $\lim_{y \rightarrow \bar{y}} \Delta(y, e) > 0$. Since the function $\Delta(y, e)$ increases in y , it follows that there is a unique solution y^{FT} to $\Delta(y, e) = 0$.

To derive the comparative statics results about the threshold behavior, consider $\phi = f/(1 - \tau)$. From (33), it can easily be seen that $\Delta_\phi < 0$ and $\Delta_r < 0$. With $\Delta_y > 0$, it then follows that

$$\frac{\partial y^{FT}}{\partial \phi} = -\frac{\Delta_\phi}{\Delta_y}(y^{FT}, e) > 0 \text{ and } \frac{\partial y^{FT}}{\partial r} = -\frac{\Delta_r}{\Delta_y}(y^{FT}, e) > 0. \quad \blacksquare$$

Proof of Proposition 2 Let $y^*(e)$ denote the e -optimal level of the ability threshold, as defined by

$$y^*(e) = \frac{1}{w_s^* e} [2w_u^* + c(e)] \quad (34)$$

(first-order condition of (17) associated to the maximization of welfare with respect to y) where to save on notation w_s^* and w_u^* are the equilibrium wages associated to that threshold. The optimum is implemented for f such that $y^{FT} = y^*(e)$.

The budget constraint (18) computed at e , the threshold $y^*(e)$ and the wages w_s^* and w_u^* determine the value of the ratio $\rho = \tau/(1-f)$ (which is smaller than 1). Now consider the expression of y^{FT} as given by (7) where the right hand side is computed at the optimal levels (including the wages) and $\tau = \rho(1-f)$.

Let us introduce the function Y of f

$$Y(f) = \frac{w_u^*(2+r)}{w_s^* e} + \frac{(1+r) f c(e)}{(1-\tau) w_s^* e}, \quad (35)$$

where the right-hand side is computed at the wages associated to the optimal level y^* and where $\tau = \rho(1-f)$.

Observe that $Y(f)$ is the threshold ability determined by individuals' behavior when these individuals expect wages to be given by w_s^* and w_u^* , the tax to be $\tau = \rho(1-f)$, and the fee to be f . Thus, the wages are not necessarily the associated equilibrium wages and the budget may not be balanced. However, for a value f for which $Y(f)$ equals the optimal threshold $y^*(e)$ the optimum is reached: the equilibrium wages will indeed be given by w_s^* and w_u^* and the budget will be balanced.

We compare $Y(f)$ and $y^*(e)$

$$Y(f) \begin{matrix} \geq \\ \leq \end{matrix} y^*(e) \quad (36)$$

$$\frac{w_u^*(2+r)}{w_s^* e} + \frac{(1+r) f c(e)}{(1-\tau) w_s^* e} \begin{matrix} \geq \\ \leq \end{matrix} \frac{1}{w_s^* e} [2w_u^* + c(e)] \quad (37)$$

Rearranging this gives

$$\frac{f}{(1-\rho(1-f))} \begin{matrix} \geq \\ < \end{matrix} \frac{[2w_u^* + c(e)] - w_u^*(2+r)}{(1+r)c(e)} = \frac{c(e) - w_u^* r}{(1+r)c(e)}. \quad (38)$$

The optimum is implemented for f such that (38) holds as an equality.

(a) For $r = 0$, equality requires $f = 1$: pure fee-financing is optimal. For $0 < r < \frac{c(e)}{w_u^*}$, the right-hand side of (38) is positive and smaller than 1 and the left-hand-side is between 0 and 1 for $f = [0, 1]$. This shows that there must be one $f \in (0, 1)$ for which there is equality, i.e. $Y(f) = y^*(e)$. Since the optimal f is smaller than 1 the optimal τ follows from the budget constraint (18) and is positive: mixed-financing is optimal. This holds for any educational level, especially for $e = e^*$.

(b) If $r > \frac{c(e)}{w_u^*}$, the right-hand side of (38) is negative. Equality of (38) then requires that also the left-hand side is negative, which follows for $f < 0$. If the level of tuition fees is restricted, $f = [0, 1]$, the left-hand side of (38) is always positive and thus larger than the right-hand side. Then $Y(f)$ approaches $y^*(e)$ from above for decreasing f and $Y(0) = y^T(e)$ is closest to the optimal threshold $y^*(e)$: pure tax-financing is second-best.

For $r > \frac{c(e)}{w_u^*}$ and $f = 0, \tau > 0$, the number of students is sub-optimal low. To show this, it is useful to compare the threshold $y^T(e)$ with a pure tax-regime with the e -optimal threshold $y^*(e)$ given by condition (17). When $f = 0$, the condition does not depend on the tax level as the threshold $y^T(e)$ does not depend on the tax rate. The threshold $y^T(e)$ solves $y - \frac{w_u(y, e)(2+r)}{w_s(y, e)e} = 0$ (see (9)) or, equivalently, the net benefit $\Delta(y, e)$ given by (33) is null where f is taken equal to zero. From the proof of Proposition 1, we know that Δ is increasing in y . Hence $y^T(e) \geq y^*(e)$, if and only if $\Delta(y, e)$ is smaller than 0 at $y = y^*(e)$, which is equivalent to $r > \frac{c(e)}{w_u^*(y^*, e)}$. ■

Proof of Proposition 3 The internal reaction is the same as in a closed economy. We show that an increase in the fee induces an increase in the net skilled wage. Consider A for instance. Following a change in the fee df^A , the tax rate varies so as to balance the budget, accounting for the impact to acquire education, i.e. the internal reaction via the ability threshold. Denoting the variation in the government budget, the tax rate, and the ability threshold respectively by $dB, d\tau^A$ and dy^A , we have

$$dB = d\tau^A F^A + [\tau^*(2w_u^A - w_s^A e y^A) + (1 - f^*)c(e)]dy^A + df^A N_s^* c(e). \quad (39)$$

The tax varies so as to balance the budget, i.e. so as to satisfy $dB = 0$. The term multiplying dy^A is the net effect on the budget of a marginal increase in the ability threshold: it is equal to the change in the amount of taxes collected on the marginal skilled worker plus the saving on educational costs. At the optimum, this net effect is positive:¹³ using that $-w_s^A e y^A + 2w_u^A + c(e) = 0$ (cf. (17)), we have $[\tau^*(2w_u^A - w_s^A e y^A) + (1 - f^*)c(e)] = (1 - f^* - \tau^*)c(e)$. Thus, the budget variation is

$$dB = d\tau^A F + (1 - f^* - \tau^*)c(e)dy^A + df^A N_s^* c(e). \quad (40)$$

We show that an increase in the fee, $df^A > 0$ induces dy^A to be positive (fewer students) and $d\tau^A$ to be negative (lower tax rate). By contradiction, let us assume dy^A to be negative. From the proof of Proposition 1, the threshold decreases only if the ratio $f/(1 - \tau)$ decreases. Using the budget equation $dB = 0$, $dy^A < 0$ implies $d\tau^A F + df^A N_s^* c(e) > 0$. Since $F > N_s^* c(e)$ and $df^A > 0$ we therefore have $d\tau^A + df^A > 0$: the possible decrease in the tax rate is smaller than the increase in the fee. This implies that $f/(1 - \tau)$ increases, i.e.

$$\frac{df}{f} + \frac{d\tau}{1 - \tau} \geq df \left[\frac{1}{f} - \frac{1}{1 - \tau} \right] \quad (41)$$

is positive since $1 - \tau^* - f^* > 0$. This gives the contradiction: dy^A is positive. Then $dB = 0$ implies that the tax rate decreases. ■

Proof of Proposition 4 Let the mixed-financing regime that implements the e -optimal threshold be in place. We consider a marginal increase in the fee of a country, say A .

If country A was closed, an increase in the fee of A results in fewer skilled workers, $y^A > y^*$, lower tax level, $\tau^A < \tau^*$, and a net increase in the skilled wage in A , as seen in Proposition 3. Now open the economy. All skilled workers in B would like to migrate to A .

As introduced in the text, consider country $x = A, B$ that experiences the extra amount m of skilled labor (which can be positive or negative) and let w_s^x, L_s^x, L_u^x , and τ^x be the equilibrium levels (associated with the threshold level). The net skilled wage is given by (30):

$$w_s^x(L_s^x + m, L_U^x)(1 - \tau^x(L_s^x + m, L_u^x)), x = A, B$$

¹³The argument below works as long as the net effect is positive.

Consider the gap in the net skilled wages between the two countries

$$Gap(m) = w_s^A(L_s^A + m, L_u^A)(1 - \tau^A(L_s^A + m, L_u^A)) - w_s^B(L_s^B - m, L_u^B)(1 - \tau^B(L_s^B - m, L_u^B)). \quad (42)$$

when m moves from A to B . The arbitrage condition writes as $Gap = 0$.

From Proposition 3 we know that for A and B closed without any migration, i.e. $m = 0$, taking $f^A > f^* = f^B$, the net skilled wage in A is larger than in B : this gives $Gap(0) > 0$. Now by the stability condition, Gap decreases with m . Increase m until either (a) Gap is null and the arbitrage condition is fulfilled or (b) τ^B reaches τ^{max} or (c) every skilled migrates to A , i.e. m is equal to L_s^B . In case (a), we are done: country A attracts some skilled workers for free. In case (b) the tax rate reaches its maximum: country B stops educating students who want to become skilled so as to migrate to country A . Country A still attracts some skilled workers for free. Case (c) never occurs before either (a) or (b) occurs: by contradiction, if there is no skilled labor remaining in country B , the skilled wage becomes arbitrarily large so that the net skilled wage in B is surely larger than in A (because τ^B is strictly smaller than 1) so that (a) is fulfilled before. ■

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