Educational Federalism: Do tuition fees improve quality and the number of students ?

Malte Hübner*
Universität Mannheim

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Abstract

I investigate how the introduction of a tuition fee in a federation affects the quality of universities and the number of students. In my model the number of students is the result of an occupational choice of heterogenous individuals. One of the central results of the analysis is that the effects of a move from a system of purely public funding to a system with private contributions can not be studied in isolation from the tax system. I find that the introduction of tuition fees can raise the number of students and quality under decentralized as well as centralized decision making when the income tax rate is low. For moderate income taxes the number of students declines although quality might improve. I identify a competition and an incentive effect that determine whether a system of centralized or decentralized funding yields more students and higher quality.

Keywords: fiscal federalism, funding of higher education, student mobility, tuition fees
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*Universität Mannheim, FB Volkswirtschaftslehre,L7, 3-5, 68131 Mannheim, email:huebner@uni-mannheim.de. I thank Eckhard Janeba and Kai Konrad for helpful comments and suggestions. All mistakes remain my own. This research was supported by the priority program 1142 of the German Research Foundation (DFG)

1 Introduction

Recently published international rankings of university performance consistently indicate that European universities lag behind their American counterparts. This lag is particularly severe for the top institutions (Aghion et al., 2007). A situation that is often attributed to differences in university funding. The U.S. does not only spend more on their universities (3.3% of GDP vs. 1.3% in Europe), but also has a much higher share of private contributions. These findings have sparked a debate about whether European countries should increase spending on higher education through more private contributions.

The debate on this issue is at present particularly intense in Germany where tuition fees were legally banned until 2005. Germany's universities are therefore funded almost exclusively out of public funds. Since 2005 the German states can autonomously decide on the introduction of tuition fees, making it possible to increase per-student expenses by raising private contributions. In 2007 a few states have already done so. The introduction of tuition fees remains however controversial. Critics point out that an increase of private contributions could lead to lower participation in higher education.

In federal states the dispute on how universities should be funded is also related to the question of how educational competencies are properly allocated between different levels of government. In general, the allocation of funding authority to lower levels of government is seen as problematic as regional governments have the opportunity to free-ride on the educational expenditure of their neighbors (Justman and Thisse, 1997, 2000). Büttner and Schwager (2003) present empirical evidence that this might be the case in Germany.

To address the postulated trade-off between higher quality and lower participation rate under different degrees of decentralization I develop a model in which universities are funded out of tax-revenue and, if available, tuition fees. Governments can control the quality of universities and tuition fees but not the income tax rate which is exogenously given. In my model the median voter is a non-working old. Governments acting on the interest of the median-voter seek to maximize transfers to the old. Therefore investments into higher education serve to increase the tax-base from which these transfers are financed. When determining their policy governments take into account the occupational choice of individuals who are heterogenous with respect to their individual costs of attending university. In my model the total number of students is therefore endogenously determined.

With this setup I can address two questions: (i) How does the fiscal regime (i.e. centralization vs. decentralization) affect the number of students and the average quality of universities in a federation and how does this result depend on the availability of tuition fees? (ii) How are these variables affected by the introduction of tuition fees under centralized and decentralized decision making? In order to answer these questions I compare the quality of universities q^r and the number of students n^r between four different regimes $r \in \{C, D\} \times \{F, NF\}$. Each regime is characterized by either central (C) or decentral (D) decision making and either pure public funding of universities (NF) or partially private funding of univiersities through tuition fees (F). A priori it is not clear which institutional setup is most beneficial to students. Under centralization the central government has some monopoly power when it sets quality and tuition fees. However in this situation there are no spill-overs between regions which are usually assumed to decrease educational investments (Justman and Thisse, 1997).

As a main result I find that the effects of an introduction of a tuition fee depends strongly on the prevailing income-tax system. At low income tax-levels, the introduction of a tuition fee can make the provision of higher education more attractive to the government which leads to higher per-capita spending on universities, higher student income and more students in turn. For moderate income tax levels however, the introduction of a tuition fee improves quality but not the number of students.

With respect to the proper allocation of educational competencies the model indicates that the number of students and educational investment are higher under decentralization if graduates are likely to stay in the region where they completed their studies. In this case regions try to attract students to increase their tax-base. If graduates are likely to leave the region after graduation then regions have an incentive to free-ride on the educational investments of the other regions, leading to less students than under centralization.

The results depend on the assumption that regional governments can not influence the migration behavior of graduates by changes of the tax-rate. This assumption is standard in the literature (Justman and Thisse, 1997, 2000; Kemnitz, 2005)and keeps the model analytically tractable.

There exists other work that examines investment in higher education in a federation. The model closest to mine is that of Kemnitz (2005) who also compares a centralized regime with decentralized decision making when governments control educational investment and tuition fees. However, in his model, the number of students in the federation is exogenously given and does not depend on government policy. This assumption is shared by Mechtenberg and Strausz (2006) who also consider the quality choice in a federation. A model where the number of students is endogenously determined is the one of Justman and Thisse (1997). However in their model the number of students is directly controlled by the government who faces an infinite supply of identical individuals. In Justman and Thisse (2000) the number of students is endogenously determined by an occupational choice as in my model, but they do not consider the possibility of private contributions through tuition fees.

The rest of paper is organized as follows: Section 2 describes the basic model and Section 3 introduces occupational and locational choice of individuals. Thereafter Section 4 describes the first-best. Sec. 5 considers the case of centralized decision making, before Sec. 6 looks at the case of decetralized decision making. Section 7 concludes.

2 The Model

I consider a federation formed by two identical regions $i = A, B$. Each region is inhabited by a continuum of young individuals of mass one which are imperfectly mobile between regions and a mass $P > 1$ of immobile old individuals.

Each region operates a university of quality q_i. An individual who attends a university of quality q_i aqcuires $H(q_i) = \sqrt{q_i}$ efficiency units of human capital.

Quality can be supplied at constant per-capita marginal costs of one. Educating n_i students at quality q_i therefore costs $C(n_i, q_i) = n_i c(q_i) = n_i q_i$, where $c(q_i) = q_i$ denote the per-capita costs of educating one student if quality is q_i. Note that we can interpret q_i also as the per-capita spending on higher education and assume that higher per-capita spending increases the human capital of graduates.

The economy produces a single good with a constant returns to scale technology to which human capital is the only input. The good is used as a consumption good as well as an input to the production of "quality". The factor price for one efficiency unit of human capital is normalized to $w = 1$.

Governments tax high-skilled at a rate τ[1]. I assume that this tax-rate is set in a political process which reflects more aspects than just the finance of higher education. Central and regional governments therefore consider this tax-rate to be exogenous. Depending on the institutional regime, local governments might be allowed to set a tuition fee t_i as an additional source of revenue.

There are two possible occupations: high-skilled and low-skilled (workers). An individual who decides to attend a university is called a high-skilled. All other individuals are referred to as low-skilled or workers. While the human capital of a high-skilled depends on the quality of the university that he attends, we normalize human capital of a low-skilled to zero. This implies that a worker earns a lifetime income of

$$I^L = 0 \tag{1}$$

while a high-skilled who attended a university in region i ends up with a lifetime income of

$$I^H(q_i, t_i) = (1 - \tau)H(q_i) - t_i \tag{2}$$

Note that $t_i = 0$ if regions are not allowed to make use of tuition fees. We can interpret (1) and (2) as the net present value of income in a two period model where the high-skilled receive education in the first period and work in the second period and interest is zero.[2]

The young are heterogenous with respect to individual migration costs μ and individual costs of studying z. Migration costs comprise non-monetary costs of living in a region other than the home region and are distributed over an interval $[-\overline{\mu}, \overline{\mu}]$. These costs can be negative to account for the fact that some individuals might want to migrate to a different region to benefit from some individual-specific amenities in the destination region even if this does not improve their

[1]Alternatively, we could assume that both high and low skilled are taxed at different rates $\tau^L \leq \tau^H$. This would not affect the results as long as income of the unskilled is constant.

[2]Under this assumption the net-present value of income depends on income in the first i_1 and second period i_2.

$$I = i_1 + (1/(1 + r))i_2$$

For workers we have $i_1 = i_2 = 0$. Students have $i_1 = 0$ because they do not work in the first period and $i_2 = I^H$ in the second period. For $r = 0$ (1) and (2) can thus be interpreted as the net present value of income.

income. Individual costs of studying z are interpreted as a combination of psychological costs of taking out a loan, opportunity costs of attending university or different degrees of ability which result in different effort levels necessary to successfully complete university. These costs are non-negative for all individuals and drawn from the interval $[0, \overline{z}]$. I assume that μ and z are uniformly and independently distributed. Because there is a mass one of young individuals in each region we have $2\overline{\mu z} = 1$. Note that neither μ, nor z are observable by the government. The heterogeneity leads individuals to endogenously sort into different occupations (see Sec.3).

Utility is linear in consumption $u(c) = c$. As individuals consume their entire income indirect utility of a type (μ, z) is therefore

$$V(q, t; \mu, z) = I^H(q, t) - \mathbf{1_M}\mu - \mathbf{1_S}z$$

where $\mathbf{1_M}$ and $\mathbf{1_S}$ are indicator variables which are 1 if an individual migrates ($\mathbf{1_M}$) or attends university in either region ($\mathbf{1_S}$). A similar assumption on preferences is made by Immervoll et al. (2007) who study a discrete working/non-working decision and individuals differ in the fixed cost of working.

We assume that central and local governments in the federation maximize the transfers to the old, who constitute a majority of the constituency. As investment in higher education increases the total income that can be redistributed to the old it functions as a basis for intergenerational distribution as in Kemnitz (2005).

It is an empirically well established fact that there is a significant degree of mobility among university graduates. Busch (2007) for instance, reports that ten-years after graduation about 30% of the German graduates live in a state that is different to the state where they completed their studies. Mohr (2002) arrives at comparable results. He finds that 18 month after graduation about one fifth of the German students work in a city that is at least 200 kilometers away from where they completed their studies. To account for high-skilled mobility I assume that an exogenous fraction $(1 - \delta)$ of the graduates from region i decide to work in region j. Although one could argue that regions possess of instruments such as the level of local public goods with influence the migration decisions of the high-skilled population this simplifying assumption greatly facilitates the subsequent analysis. The assumption that an exogenously given fraction of graduates chooses to migrate is also quite standard in the literature (see for instance Justman and Thisse (1997)).

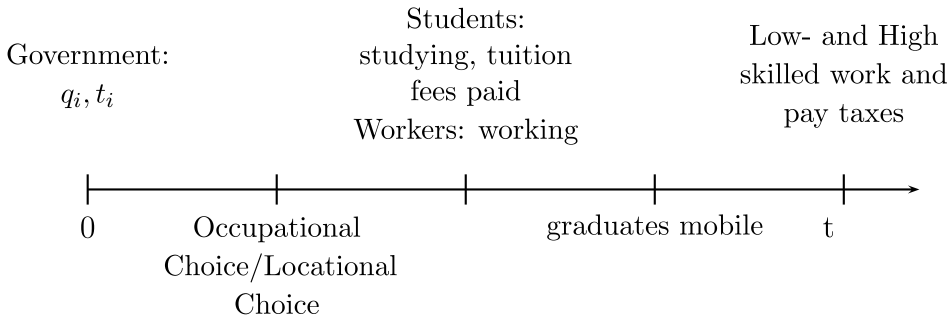

Figure 1: timeline

Having described preferences and technologies of the model I now turn to a description of the sequencing of decisions for individuals and governments in this economy. The timeline of the model is summarized in Fig.2: First, governments choose the per-capita expenditure on students and (if available) tuition fees. Upon observing these variables individuals make an *occupational* and *locational choice*. Thereafter students attend university, acquire human capital and pay tuition fees. After graduation a fraction $(1 - \delta)$ of the high-skilled migrates to the other region, while workers are immobile. Thereafter the high-skilled work and pay taxes.

The model is now analyzed backwards, beginning with the occupational and locational choice of the individuals. Thereafter, the governments decision are analyzed.

3 Occupational and Locational Choice

The occupational choice of individuals is of central importance to the model as it allows to analyze how government policy affects the number of students. The policy choices (q_A, t_A) and (q_B, t_B) made in the first stage of the model determine the level of utility that an individual (μ, z) in region i can achieve, depending on whether he decides to become high-skilled or low-skilled (occupational choice) as well as on his migration decision (locational choice). Let $V_{ii}^L(\mu, z)$ $(V_{ij}^L(\mu, z))$ denote the utility that he achieves as a low-skilled in region i (j). If $V_{ii}^H(\mu, z)$ $(V_{ij}^H(\mu, z))$ refers to the utility that he obtains as a high skilled after having studied in i (j) then the locational and occupational choice corresponds to a discrete choice from the alternatives $\{V_{ii}^H, V_{ij}^H, V_{ii}^L, V_{ij}^L\}$. This choice is now analyzed in detail.

As individuals spend all their income on consumption a low-skilled of type (μ, z) in region i reaches an utility level $V_{ii}^W(\mu, z) = 0$ if he works at home and $V_{ij}^W(\mu, z) = -\mu$ if he works in foreign. Similarly, an individual from region i reaches a utility level $V_{ii}^S(\mu, z) = (1 - \tau)H(q_i) - t_i - z$ if he studies at home and $V_{ij}^S(\mu, z) = (1 - \tau)H(q_j) - t_j - z - \mu$ if he studies abroad.

We first analyze the choice of an occupation: An individual of region i prefers studying in i to working in i iff $V_{ii}^W \leq V_{ii}^S$; i.e. if and only if his individual costs of studying do not exceed the net income of a student in region i

$$z \leq I^S(q_i, t_i) \equiv z_i(q_i, t_i) \tag{3}$$

The same individual prefers studying in j to working in j iff $V_{ij}^W \leq V_{ij}^S$, or

$$z \leq I^S(q_j, t_j) \equiv z_j(q_j, t_j) \tag{4}$$

Equations (3) and (4) define two *marginal types* z_i and z_j who are indifferent between working at home (abroad) and studying at home (abroad). For the further analysis it is important to note that the critical type z_i in region i corresponds to the net-lifetime income of a high-skilled educated in region i.

Fig. 2 shows the marginal types z_i and z_j for a situation in which both regions have chosen identical levels of quality and tuition fees. The assumption of a uniform distribution for μ and z allows us to arrange all individuals of a region in a box. Where an individual is located in this box depends on its type (μ, z). The individuals with zero costs of attending university and migration costs $-\overline{\mu}$ are located at the left bottom corner. The higher the individual costs of attending university the more to the right an individual is positioned. Migration costs increase from bottom to top. We see that the critical types z_i and z_j divide the population into low-skilled (to the right of z_i, z_j) and high-skilled (to the left of the critical types).

While equations (3) and (4) describe the occupational choice, in addition, each individual has to make a locational choice and decide in which region to work or study. An individual from region i prefers studying in j to studying in i only if the former option gives him a higher utility: $V_{ij}^H > V_{ii}^H$, or

$$\mu < (1 - \tau)(H(q_j) - H(q_i)) + t_i - t_j = z_j - z_i \equiv \mu_i(z_i, z_j) \tag{5}$$

Because the specific costs of studying have to born in both regions, the individual only compares the costs of migrating μ to the income gain from studying abroad $z_j - z_i$. Individuals study in their home region if their migration costs are at least as high as the income gain from studying in the other region. Equation (5) defines a critical type μ_i who is just indifferent between studying at home and abroad. Figure 2 shows that μ_i divides the high-skilled into those educated at home (individuals with $z \leq z_i$ and $\mu \geq \mu_i$) and those who migrated to receive education in a different region (individuals with $z \leq z_j$ and $\mu < \mu_i$). Region i individuals who decide to remain low skilled prefer working in j to working in i if they can realize a higher utility level by migrating, i.e. if and only if $V_{ij}^W > V_{ii}^W$, or

$$\mu < 0$$

As the lifetime income of a low-skilled is independent from the region in which he works, his utility only depends on his migration costs. He therefore works abroad if and only if his home attachment (migration costs) is negative.

workers earn the same net lifetime income everywhere, they work abroad if and only if their home attachment is sufficiently low. We can calculate the number of "home" students in region i, n_{ii}, the number of region i students who study in j, n_{ij} and the number of region i workers at home l_{ii} and abroad l_{ij}:

$$n_{ii} = (\overline{\mu} - \mu_i) z_i \tag{6}$$

$$n_{ij} = (\overline{\mu} + \mu_i) z_j \tag{7}$$

$$l_{ii} = (\overline{\mu} - \mu_i)(\overline{z} - z_i) \tag{8}$$

$$l_{ij} = (\overline{\mu} + \mu_i)(\overline{z} - z_j) \tag{9}$$

Note that the last equalities in (6)-(9) follow from the assumption that μ and z are independently and uniformly distributed.

When the government chooses tuition fees and quality the marginal types z_i, z_j (and thus also μ_i and μ_j) are uniquely determined by (3)-(5). We can therefore reformulate the governments problem such that it sets tuition fees t_i and the critical type z_i. Quality $q_i = q_i(z_i, t_i)$ is then determined as a residual according to (3). Given tuition fees t_i and the critical type z_i quality adjusts to make individuals of type z_i indifferent between studying and working. This is the case if

$$H(z_i, t_i) = \frac{z_i + t_i}{1 - \tau}$$

We see that for a given critical student z_i an increase in tuition fees t_i requires that this students earns a higher gross income to keep him indifferent between studying and working. For $H(q) = \sqrt{q}$ we have $c(q) = R(q)^2$ and thus $c(z,t) = R(z,t)^2$, which implies

$$q(z,t) = c(z,t) = \left(\frac{z+t}{1-\tau}\right)^2 \tag{10}$$

Increasing the tuition fees while keeping z_i constant raises the per-capita costs for a student because students have to be provided with higher quality to keep types z_i indifferent between studying and working. Because students with higher costs of studying require more quality to be indifferent between studying and working, the average costs of educating a student increases with z_i.

We can now look at how a change of z_i and z_j affects the number of students in region i. From (6) and (7):

$$\frac{\partial n_{ii}}{\partial z_j} = -z_i \tag{11}$$

$$\frac{\partial n_{ij}}{\partial z_j} = (\overline{\mu} + \mu_i) + z_j \tag{12}$$

Fig. (3) shows the effect of an unilateral increase Δz_j of z_j on the choices of region i residents. This change has two effects: Firstly, a higher z_j means a higher net income for students in j. There are some individuals in region i who decided to work at home but find it now worthwhile to study in region j. The number of region i individuals who study in j increases by $(\overline{\mu}+\mu_i)\Delta z_j$ (this is area B in Fig. 3). This effect corresponds to a shift of z_j to the right along the horizontal axis in Fig. (3) and is captured by the first term in (12). Secondly, if the net lifetime income of high-skilled educated in region j increases then some of the region i individuals who decided to study at home now find it worthwhile to study in region j. This corresponds to an upward movement of μ_i. The number of region i students in j increases by $z_j \Delta z_j$ (this is area A in Fig. 3 and the second term in (12)).

Now we consider a change of the marginal type z_i on the choices made by residents of region i. Recall that this critical type corresponds to the net lifetime income of someone who attended university in region i. If this income changes the number of individuals in region i who decide to attend a university in region i and j is affected in the following way:

$$\frac{\partial n_{ii}}{\partial z_i} = (\overline{\mu} - \mu_i) + z_i \tag{13}$$

$$\frac{\partial n_{ij}}{\partial z_i} = -z_j \tag{14}$$

Again there are two effects: an increase in the net lifetime income of high-skilled educated in region i reduces the number of region i individuals who study abroad and thus increases the number of home students (this is the second term in (13)). Secondly, an increase in the net-income of a student on region i makes studying attractive to some students who decided to work in i before this change (this is the first-term in (13)).

In the sequel I denote by n_i the total number of students in region i, regardless of their origin; i.e. $n_i = n_{ii} + n_{ji}$. From (12)-(13) we then have

$$\frac{\partial n_i}{\partial z_i} = \frac{\partial (n_{ii} + n_{ji})}{\partial z_i} = 2z_i + (\overline{\mu} - \mu_i) + (\overline{\mu} + \mu_j) \tag{15}$$

$$\frac{\partial n_i}{\partial z_j} = \frac{\partial (n_{ii} + n_{ji})}{\partial z_j} = -2z_i \tag{16}$$

The reaction of the number of students in a region to change of the critical type z_i in that region, as described by (15), can be decomposed into two effects: the first term describes the reaction of the distribution of students across regions. It measures how many students move from region j to i if region i chooses a policy that improves net-income for students in region i. The latter two terms describe the number of additional individuals that decide to become high-skilled when the income for high-skilled increases.

With a description of the basic set-up and occupational choice in place we can now analyze the equilibrium level of quality and tuition fees under different institutional regimes. To have a reference point for this analysis let us first consider the choices made by a social planner.

4 First-Best

A social planner who maximizes total output of the federation net of the costs for providing higher education solves the following maximization program

$$\max_{z_A,z_B,t_A,t_B} \sum_{i=A,B} n_i(z_i) \underbrace{(H(z_i,t_i) - c(z_i,t_i))}_{\equiv \pi}$$

where $\pi = H(z_i,t_i) - c(z_i,t_i)$ is the net output generated by a student in region i. The first-order conditions for this problem are

$$\frac{\partial n_i}{\partial z_i}\pi(z_i,t_i) + n_i\frac{\partial \pi}{\partial z_i} + \frac{\partial n_j}{\partial z_i}\pi(z_j,t_j) = 0 \tag{17}$$

$$n_i\frac{\partial \pi}{\partial t_i} = 0 \tag{18}$$

From (18) and (10) we obtain

$$q^* = \frac{1}{4} \tag{19}$$

Plugging this into the governments budget constraint $c(q^*) = \tau H(q^*) + t$ we obtain[3]

$$t^* = \frac{1}{4} - \frac{1}{2}\tau \tag{20}$$

$$n^* = \frac{1/4}{\overline{z}} \tag{21}$$

Equation (21) tells us that in this model it is efficient to send only those individuals to university whose individual costs of studying do not exceed $z^* = 1/4$. To make studying attractive for individuals of type $z > 1/4$ would require to set an inefficiently high quality level.

5 Centralization

5.1 Tuition Fees

In a centralized regime with tuition fees there is a central government that sets tuition fees (t_A, t_B) and quality of universities (q_A, q_B) to maximize net government revenue. The objective of the government is therefore formally described by:

$$\max_{t_A,t_B,z_A,z_B} \sum_{i=A,B} n_i(z_i)\pi^D + (1-\delta)\tau n_j(z_j)H(z_j,t_j)$$

[3]The latter equation follows from $z^* = (1-\tau)H(q^*) - t^*$

where $\pi^D = \delta\tau H(z_i, t_i) + t_i - c(t_i, z_i)$ is the per-capita revenue from each student educated in region i. Note that $\delta\tau H(z_i, t_i)$ is the tax-revenue from region i students remaining in region i after graduate migration. Similarly $(1-\delta)\tau n_j(z_j)R(z_j, t_j)$ is the tax-revenue from students educated in region j which accrues to region i because graduates decide to work there. As the central government collects revenue from both regions, graduate mobility does not influence the government decision. The above maximization problem is therefore equivalent to

$$\max_{t_A, t_B, z_A, z_B} \Pi^{CF} = \sum_{i=A,B} n_i(z_i) \underbrace{(\tau H(z_i, t_i) + t_i - c(t_i, z_i))}_{\equiv \pi^Z(z_i, t_i)} \tag{22}$$

We see that the government ignores graduate mobility $(1-\delta)$ as it collects revenue from both regions. Let us denote by $\pi^Z(z_i, t_i)$ the net revenue from educating a student in region i under centralization. The first-order conditions for (22) are

$$z_i \quad : \quad \frac{\partial n_i}{\partial z_i}\pi^Z(z_i, t_i) + n_i \frac{\partial \pi^Z(z_i, t_i)}{\partial z_i} + \frac{\partial n_j}{\partial z_i}\pi^Z(z_j, t_j) = 0 \tag{23}$$

$$t_i \quad : \quad n_i \frac{\partial \pi^Z(z_i, t_i)}{\partial t_i} = 0 \tag{24}$$

Equation (24) implies that quality is independent of the tax-rate τ and equal to the first-best

$$q^{ZF} = (H(z_i, t_i))^2 = 1/4 \tag{25}$$

After plugging (24) into (23) and setting $z_A = z_B = z$ and $t_A = t_B = t$ to solve for a symmetric equilibrium (23) becomes

$$\overline{\mu}\pi^z(z, t) + \overline{\mu} z \frac{\partial \pi^z(z, t)}{\partial z} = 0 \tag{26}$$

Equation (26) illustrates the trade-off that the government has to consider when it chooses the critical type z. There are two effects that need to be balanced against each other: Firstly, leaving students a higher net-income z leads to more high-skilled individuals and therefore to more revenue. This is captured by the first term in (26). Secondly, when the government leaves the high-skilled a higher net-income z by providing higher quality or setting lower fees this reduces the per-capita revenue from each high-skilled. This is described by the second term in (26). Solving (26). for z we obtain

$$n^{ZF} = \frac{1/8}{\overline{z}} \tag{27}$$

$$t^{ZF} = \frac{3}{8} - \frac{1}{2}\tau \tag{28}$$

Comparing (21) and (27) we see that the number of high-skilled is lower than in the first-best, although the quality of universities is the same. Obviously the government sets the quality of universities to the output maximizing level q^* and then uses the tuition fees to extract revenue from the students ($t^* < t^{CF}$). We have the following

Result 1 *Under a centralized regime with tuition fees quality is equal to the first-best, but the number of students is inefficiently low.*

The intuition for this result can easily be seen when comparing the objective functions of the social planner and the central government. Because the latter maximizes only governments revenue and ignores the income of the high-skilled, the marginal return per student is lower than in the first-best, leading to lower quality and less students.

5.2 Pure Public Funding

In a centralized regime with pure public funding, the central government sets q_A and q_B. The optimization program of the central government is therefore the same as in (22) with tuition fees set to zero. The government therefore maximizes

$$\max_{z_A, z_B} \Pi^{CNF} = \sum_{i=A,B} n_i(z_i)\pi^Z(z_i, 0) \tag{29}$$

The first-order conditions for this problem are

$$z_i \quad : \quad \frac{\partial n_i}{\partial z_i}\pi^Z(z_i, 0) + n_i \frac{\partial \pi^Z(z_i, 0)}{\partial z_i} + \frac{\partial n_j}{\partial z_i}\pi^Z(z_j, 0) = 0 \tag{30}$$

When we look for a symmetric solution $z_A = z_B = z^{CNF}$ (29) becomes

$$\overline{\mu}\pi^z(z^{CNF}, 0) + \overline{\mu}z\frac{\partial \pi^z(z^{CNF}, 0)}{\partial z} = 0 \tag{31}$$

The government therefore faces the same trade-off as in the centralized regime with tuition fees. Solving (30) yields

$$n^{CNF} = \frac{z^{CNF}}{\overline{z}} = \frac{2}{3}\tau(1-\tau)\frac{1}{\overline{z}} \tag{32}$$

Using (25) we obtain

$$q^{CNF} = \frac{4}{9}\tau^2 \tag{33}$$

It is easily verified that the SOC

$$\frac{\partial^2 \Pi^{CNF}}{\partial^2 z_i} = \frac{\partial^2 n_i}{\partial^2 z_i}\pi^Z + 2\frac{\partial n_i}{\partial z_i}\frac{\partial \pi^Z}{\partial z_i} + n_i\frac{\partial^2 \pi^Z}{\partial^2 z_i} < 0 \tag{34}$$

holds at (32). From (32) and (33) we obtain the

Result 2 *Under a centralized regime with tuition fees quality is equal to the first-best, but the number of students is inefficiently low.*

The reason lies again in the diverging interest of the social planner, who maximizes output and the central government, which maximizes revenue.

How does the introduction of a tuition-fee into a centralized regime affect the quality of universities and the number of students? By comparing (25) and (27) with (32) and (33) we obtain the following

Result 3 *Under decentralized decision making the introduction of a tuition increases the number of students if $\tau \in [0, 1/4) \cup (3/4, 1]$. For all other tax-levels the introduction of a tuition fee leads to declining number of students. The introduction of a tuition fee leads to higher (lower) quality if $\tau < 3/4$ ($\tau > 3/4$).*

The intuition for this result is straightforward. In the absence of tuition fees the ability of the government to extract revenue from the students depends on the level of the income tax. For low levels of this tax the marginal revenue from investment into education is low, causing the government to set low levels of quality (33). As low quality translates into low student income, low income-tax rates thus imply a low number of students. If a tuition fee becomes available in this situation, the government is able to extract more revenue from the students. Facing a higher marginal revenue the government invests more into education, resulting in higher quality. At a low quality level such an increase raises income of the high-skilled by an amount which more than offsets the tuition fee. Studying becomes more attractive and leads to higher number of students. For "moderate" tax-levels $\tau \in [1/4, 3/4)$ the introduction of a tuition fee leads to higher quality. However, here the increase in human capital and hence gross income is lower than the tuition fee, leading to lower number of high-skilled.

At high income tax-level of $\tau > 3/4$ the government chooses high levels of quality. However, due to the high income tax-rate the net-income of a high-skilled is low. Consequently, less individuals decide to attend university. If a tuition fee becomes available in this situation the government uses it to subsidize students. This raises the lifetime income of the high-skilled and the number of students. We therefore have the following

Proposition 5.1 *Under centralized decision making and for extreme taxes; i.e.* $\tau \notin [\frac{1}{4}.\frac{3}{4}]$ *the introduction of a tuition fee leads to a pareto-improvement.*

Proof Let τ be such that the introduction of a tution fee raises the marginal type from $\hat{z}$ to $\hat{z}'$ with $\hat{z} < \hat{z}'$. We have to show that none of the old and the young is worse off under this change. As the interests of the government are perfectly aligned with those of the old this part of the population must be better off whenever the government chooses a $t > 0$ (Note that the government can always choose $t = 0$). We now turn to the young: Consider first a home student with costs of attending university z. Indirect utility before and after the introduction if tuition fees is $\hat{V} = \hat{z} - z$ and $\hat{V}' = \hat{z}' - z$ respectively. We see immediately that $\hat{V}' > \hat{V}$. Now consider an individual of type (z, μ) from region i who decided to study in j. Again it is easy to see that he is better off: $\hat{V} = \hat{z} - z - \mu < \hat{V}' = \hat{z}' - z - \mu$. We now turn to the workers: Utility of an individual who remains a worker after the change of the critical type remains unaffected, so he does not loose from the policy change. An individual who decided to work before the policy shift and decides to study afterwards must be better off (otherwise he would continue to work). ∎

6 Decentralization

Having analyzed the case in which universities are financed by the federal government we now analyze the decentralized provision of higher education. When the level of investment into higher-education is set by sub-national governments the revenue accruing to the government in region $i \in \{A, B\}$ is

$$\Pi^{DF}(z_i, z_j, t_i, t_j) = n_i \pi^D(z_i, t_i) + n_j(1-\delta)\tau H(z_j, t_j) \tag{35}$$

where $\pi^D(z_i, t_i) = \delta\tau H(z_i, t_z) + t_i - c(z_i, t_i)$ is the per-capita revenue the government receives from a student it educates.

We now analyze how the equilibrium number of educational investment and the number of students depends on whether universities are purely publicly funded or whether the government is allowed to determine the share of private contributions. We start with the latter situation in which local governments are allowed to levy a tuition fee t_i.

6.1 Tuition Fees

In a regime in which governments are allowed to determine the level of private contributions to the funding of universities the problem of the local government in region i is to set tuition fees t_i and quality q_i to maximize (35), taking the policy (t_j, q_j) of the other region as given. The decision of the government are characterized by the following first-order conditions:

$$z_i \;:\; \frac{\partial n_i}{\partial z_i}\pi^D(z_i, t_i) + n_i \frac{\partial \pi^D(z_i, t_i)}{\partial z_i} + \frac{\partial n_j}{\partial z_i}(1-\delta)\tau R(z_j, t_j) = 0 \tag{36}$$

$$t_i \;:\; n_i \frac{\partial \pi^D(z_i, t_i)}{\partial t_i} = 0 \tag{37}$$

Using the fact that $H(z,t)^2 = q$, equation (37) implies

$$q^{DF} = \left(\frac{1-\epsilon}{2}\right)^2 \tag{38}$$

where $\epsilon = \tau(1-\delta)$ measures the spill-over of investment in higher education caused by graduate mobility. To understand the root of this spill-over recall that a high-skilled individual who attended university in region i pays taxes $\tau H(z_i, t_i)$ to the government in the region in which he works. However, only with a probability δ is this this region identical to the one where he received higher education. When a region decides on the level of its expenditures on higher education it expects to loose a fraction $(1-\delta)$ of the tax-payments of its former students. This spill-over distorts the choice of investment into higher education.

Note that in case universities are purely privately funded ($\tau = 0$), there is no externality and governments choose the first-best quality level. This observation gives rise to the following

Result 4 *If the average per-student tax-loss ϵ is greater than zero, then quality under decentralization with fees is lower than under centralization with fees. For all $\epsilon > 0$ there is underprovision of quality relative to the first-best.*

To solve for the marginal type z in a symmetric equilibrium plug (37) into (36) and set $t_A = t_B = t^{DF}$ and $z_A = z_B = z^{DF}$. One then finds that there is only one $z^{DF} \geq 0$ that solves (36):

$$z^{DF} = \frac{B(\epsilon) + \sqrt{B(\epsilon)^2 + (1-\epsilon)^2 \overline{\mu}}}{2} \tag{39}$$

Under what conditions does the equilibrium characterized by (39) exist? It turns out that we need to impose some restrictions on the mobility of students:

Lemma 1 *There exists a $\overline{\mu}_0$ such that for all $\overline{\mu} > \overline{\mu}_0$ the symmetric equilibrium characterized by (39) exists.*

Proof See the appendix

To gain some intuition for the condition under which a symmetric equilibrium exists note that the elasticity of the migration decision of the high skilled in such an equilibrium $\frac{\partial n_i}{\partial z_i} \frac{z_i}{n_i} = 1 + \frac{z}{\overline{\mu}}$ declines with $\overline{\mu}$. Lemma 1 therefore requires that the migration decision of students does not respond too elastically to changes in the policy of one region.

Differentiation of (39) shows that the equilibrium number of students in a symmetric equilibrium declines with the average tax-loss

$$\frac{\partial z^{DF}}{\partial \epsilon} < 0$$

Recall that one of the main objectives of our analysis was to compare the number of students and the quality of universities under decentralized and centralized decision making. The following Lemma establishes that when universities are funded with the help of private contributions, the number of students under decentralization exceeds that under centralized decision making when the fiscal externality ϵ is sufficiently small.

Lemma 2 *For all $\overline{\mu}$ there exists an $\epsilon_0 \geq 0$ such that for all $\epsilon \geq \epsilon_0$ there are more students under ZF than under DF.*

Proof See the appendix.

Note that Lemma 2 says that for low levels of the fiscal externality ϵ decentralization benefits students although the quality of universities is lower than under centralization. To gain some intuition for this result consider again (36). Rewriting and imposing symmetry yields

$$\begin{aligned}\overline{\mu}\pi^Z + \overline{\mu}z\frac{\partial \pi^Z(z,t)}{\partial z} &+ z[(2\delta - 1)\tau H(z,t) - c(z,t)] \\ &- \tau(1-\delta)[2\overline{\mu}H(z,t) + zH(z,t)] = 0\end{aligned} \tag{40}$$

The first two terms are identical to the first-order condition under centralization. They correspond to the basic trade off between more revenue through more students which comes at the price of lower per-capita revenue. Under decentralized decision making there are two additional effects represented by the latter two terms in (40):

Firstly, under decentralized decision making, lifetime income of a high-skilled z potentially depends on his locational choice. If for instance region A sets a policy that is more in favor of students than region B the lifetime income of high-skilled who attended university in region A exceeds that of region B students ($z_A > z_B$). As the locational choice of individuals responds to differences in lifetime income a region i can attract more students by increasing z_i. Whether regions have an incentive to do so depends on the probability δ that a student works in the region where he attended university. If this probability exceeds $(3-\epsilon)/4$ then the average per-student profit $2(\delta-1)R(z^{DF}) - c(z^{DF})$ to a region is positive. In this case attracting students from abroad increases marginal government revenue relative to centralization. Competition for future tax-payers tends to lead to a higher equilibrium z. For $\delta < (3-\epsilon)/4$ the third term in (40) becomes negative as students educated in one region are likely to pay taxes in the other region. In this case the marginal revenue to a local government from educating an additional student is lower than under centralization. I will refer to this effect as the *competition effect*.

In addition there is an *incentive effect* which unambiguously reduces marginal revenue from investment in quality. This effect is again caused by graduate mobility and corresponds to the last term in (40), which is always negative. Note that for $\delta > (3-\epsilon)/4$ incentive and competition effect work in opposite directions. The parameter $\overline{\mu}$ measures the relative strength of the incentive effect. This explains Result 2. The higher $\overline{\mu}$ the stronger the incentive effect and the higher must be δ for the competition effect to outweight the incentive effect.

The mechanism underlying Lemma 2 and Result 4 can now be understood as follows: Given that the fiscal externality ϵ is positive some of the investment into higher-education spills over to the other region thus leading to lower investments and quality q. However, if the high-skilled are sufficiently likely to pay taxes in the region where they attended university then governments engage in competition for future tax-payers by lowering tuition fees. If graduate mobility is sufficiently low than this reduction in tuition fees exceeds the income loss from quality of lower quality at universities.

6.2 Pure Public Funding

We now analyze the decentralized provision of higher-education under the assumption that universities must be exclusively funded out of local tax-revenue. In this case the revenue accruing to a government in region $i \in \{A, B\}$ is

$$\Pi^{DNF}(z_i, z_j) = n_i \pi^D(z_i, 0) + n_j(1-\delta)\tau H(z_j, 0) \tag{41}$$

where π^D is defined as before. In the first-stage of the game, the government in region i sets z_i to maximize (41), taking the decision of the other region as given. The equilibrium marginal type z_i is then defined by the following first-order condition:

$$z_i \quad : \quad \frac{\partial n_i}{\partial z_i}\pi^D(z_i, 0) + n_i \frac{\partial \pi^D}{\partial z_i} + \frac{\partial n_j}{\partial z_i}(1-\delta)\tau H(z_j, 0) = 0 \tag{42}$$

To solve for a symmetric equilibrium set $z_A = z_B = z$. Equation (42) then becomes

$$\begin{aligned}\overline{\mu}\pi^Z + \overline{\mu} z \frac{\partial \pi^Z(z,0)}{\partial z} &+ z[(2\delta - 1)\tau R(z,0) - c(z,0)] \\ &- \tau(1-\delta)[2\overline{\mu}R(z,0) + zR(z,0)] = 0\end{aligned} \tag{43}$$

We see that the equilibrium income of a high skilled depends again on the competition and incentive effect as in the regime with tuition fees. In (43) the third term corresponds to the competition effect and the last term represents the incentive effect. Defining A as $\tau(1-$

$\tau)(2\delta-1)-3\overline{\mu}$ it is possible to show that there is only one symmetric equilibrium with $z^{DNF}>0$.

$$z^{DNF}=\frac{A+\sqrt{A^2+8\overline{\mu}\delta\tau(1-\tau)}}{2} \tag{44}$$

Again, a sufficient condition for the existence of this symmetric equilibrium is that individuals do not react to elastically to changes in quality when deciding in which region to study. The following lemma establishes this result.

Lemma 3 *There exists a $\overline{\mu}_0'$ such that for all $\overline{\mu}>\overline{\mu}_0'$ the symmetric equilibrium given by (44) exists.*

Proof See the appendix

It is easy to see that lower graduate mobility increases the equilibrium number of students

$$\frac{\partial n^{DNF}}{\partial\delta}=\frac{1}{\overline{z}}\frac{\partial z^{DNF}}{\partial\delta}=\frac{1}{2}\left(\frac{\partial A}{\partial\delta}+\frac{A\partial A/\partial\delta+4\overline{\mu}\tau(1-\tau)}{\sqrt{A^2+8\overline{\mu}\delta\tau(1-\tau)}}\right)>0 \tag{45}$$

By evaluating (44) at $\tau=0$ and $\tau=1$ it is easily verified that $z^{DNF}|_{\tau=0}=z^{DNF}|_{\tau=1}=0$. Furthermore

$$\frac{\partial z^{DNF}}{\partial\tau}=(1-2\tau)[(2\delta-1)+\frac{(2\delta-1)A+4\overline{\mu}\delta}{2z^{DNF}-A}] \tag{46}$$

so $\frac{\partial z^{DNF}}{\partial\tau}|_{\tau=0}>0$ and $\frac{\partial z^{DNF}}{\partial\tau}|_{\tau=1}<0$. Further inspection of (46) shows that z^{DNF} has a unique maximum at $\tau=1/2$[4]. Hence the graph of z^{DNF} when plotted against τ takes a similar form as under centralization. Figure 5 shows this graph for different levels of δ. The basic mechanisms of the centralized regime are still at work under decentralization. At $\tau=0$ the government has no means to share the rents with the students and therefore lacks any incentive to invest in education. The number of students is zero. At $\tau=1$ the net income of students is zero, regardless of the quality of universities, as the government cannot use tuition fees as a subsidy. Again, no individual decides to become a student.

As in the case with tuition fees, the equilibrium level of net-student income z^{DNF} depends on the relative strength of the competition and

[4]Uniqueness follows from the fact that (**??**) is quadratic.

incentive effect. As (45) shows, less graduate mobility makes investment in education more profitable and leads to higher net-student income. This effect is the stronger the more important the competition effect (lower $\overline{\mu}$). We can prove the following

Lemma 4 *There exists a* $\delta^0 = \delta^0(\overline{\mu}) \in [0, 5/6)$ *such that*

1. $z^{DNF} \geq z^{CNF}$ *if and only if* $\delta \geq \delta^0$
2. δ^0 *is increasing in* $\overline{\mu}$.

Proof See the appendix.

Corollary 6.1 *There exists a* $\delta^0 = \delta^0(\overline{\mu}) \in [0, 5/6)$ *such that*

1. $q^{DNF} \geq q^{CNF}$ *if and only if* $\delta \geq \delta^0$
2. δ^0 *is increasing in* $\overline{\mu}$.

Proof Follows immediately from the fact that $q^r = (\frac{z^r}{1-\tau})^2$ for $r \in \{DNF, CNF\}$. ∎

Lemma 4 and Corollary 6.1 are summarized by the following

Result 5 *In the absence of tuition fees the number of students (quality) in a symmetric equilibrium depends on the relative strength of the competition and incentive effect. The number of students (quality) under decentralization is higher than under decentralized decision making when the incentive effect is weak and the competition effect relatively strong. As the competition effect gets weaker, the parameter range for which decentralization dominated centralization with respect to the number of students (quality) becomes smaller.*

Figure 7 shows z^{DNF} for different levels of $\overline{\mu}$. We see, that when graduate mobility is low (high δ) a strong competition effect (i.e. a lower $\overline{\mu}$) leads to a higher net-income for students as regions try to attract students. For low δ this effect is reversed: governments prefer students to be educated in the other region, anticipating the high outflow of graduates.

So far, results 2 and 5 allow us to compare centralized with decentralized decision making. Students benefit (i.e. the number of students is higher) under decentralization if the competition effect dominates the incentive effect. This qualitative result holds for a regime with and without tuition fees. To be able see how the introduction of tuition fees into a decentralized system affects the number of students we need the following

Lemma 5 *There exists τ_1 and τ_2 such that for all $\tau < \tau_1$ or $\tau > \tau_2$ we have $z^{DF} > z^{DNF}$. There exists parameters δ and $\overline{\mu}$ such that $[\tau_1, \tau_2) = \emptyset$.*

Figure A illustrates this situation.

Proof We have already established that $z^{DNF}|_{\tau=0} = z^{DNF}|_{\tau=1} = 0$. Inspection on (39) shows that $z^{DF} > 0$ iff $\delta > 0$. Together with the fact that z^{DNF} follows a Laffer-Curve follows the first part of the proposition. We need to show that there exists parameters δ and $\overline{\mu}$ such that $z^{DF} > z^{DNF}$ for all $\tau \in [0, 1)$. $\delta = 0$ is such a parameter. ∎

The intuition for this result is essentially the same as under centralization. The introduction of a tuition fee leads to a higher equilibrium number of students if the income tax is either very high or very low. In the first case the availability of a tuition fee improves the incentives of the government to invest in quality. Higher quality increases the income of students by more than the tuition fee. The number of students rises. In the case of very high taxes the government uses the fee as a subsidy, thus increasing the number of students. For moderate taxes, the income gain due to higher quality is more than offset by the expenditure for tuition fees so the number if students declines relative to a pure-public funding of universities.

To compare the quality of universities under decentralized decision making with and without tuition fees we need the following

Lemma 6 *For all $\overline{\mu}, \delta$ there exists a $\tilde{\tau}$ such that the following holds*

$$q^{DF} > q^{DNF} \Leftrightarrow \tau \leq \tilde{\tau}$$

Proof See the appendix

This directly implies

Result 6 *If taxes are low the introduction of tuition fees into a system of decentralized decision making raises the quality of universities.*

The intuition for this result is the same as under centralization. At low tax-levels and in the absence of tuition fees the governments lack sufficient instruments to extract revenue from the high-skilled. The marginal revenue to higher quality is thus low, leading to low quality levels. When tuition fees become available in this situation governments are able to extract more revenue, which strengthens the incentives to invest in quality.

7 Conclusion

In Germany there has been a considerable public debate about the putative effects of a move from a purely publicly funded university system towards a system with private contributions. Opponents of a tuition fee were mainly concerned that the introduction of tuition fees would reduce the number of students from poor households. Advocates of tuition fees however claimed that raising private contributions would increase quality of universities. More attractive universities would then lead to more students. Another dimension of the discussion on the funding of universities consists of the allocation of funding responsibility to the proper level of government.

So far, the public finance literature provides little guidance if one wants to predict how a change along any of the two dimensions (public vs. private funding and decentralized vs. centralized decision making) affects the number of students. Most studies of the subject were either confined to an exogenously given number of students or considered only purely publicly funded universities.

To contribute to the understanding of this subject I develeoped a model where the number of students is the result of an occupational choice of heterogenous individuals and thus endogenously determined.

With respect to the first-dimension, the analysis suggests that the effects of the introduction of a tuition fee can not be studied independently of the tax system. If the government lacks sufficient instruments to tax the high-skilled population (e.g. low income tax rates) then the introduction of a tuition fee can raise both quality and the number of students. In this case the increase in students income exceeds the tuition fee, yielding a higher net income for the high-skilled and makes studying more attractive. This is an effect that has often been overlooked in the public debate.

Does centralized provision dominate decentralization as suggested by many prior studies, e.g. Justman and Thisse (1997) and Büttner and Schwager (2003)? Here the model suggests that the answer depends on a the perceived mobility of graduates. Graduate mobility introduces a fiscal externality rooted in fact that universities are at least partly financed out of tax-revenue which might be benefit a region that did not finance the education of the tax-payer. This externality favors centralization over decentralization. However, if graduates are sufficiently likely to stay in the region where they completed their studies a high quality of universities or low tuition fees might attract additional taxpayers. In this case "competition" for students might increase quality and participation rate. Whether there are more or less students under centralization depends on the relative strength of these effects.

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A Appendix

Proof of Lemma 1

Let $BR_i^{DF}(z_j)$ be the best-response function for region i that is implicitly defined by (36). To prove the lemma we show that $BR_i^{DF}(z^{DF}) = z^{DF}$. It is sufficient to show that $\Pi(z_i, z^{DF})$ is concave on $z_i \geq 0$. We will therefore show that the second-order condition

$$\frac{\partial^2 \Pi^{DF}(z_i, z^{DF})}{\partial^2 z_i} < 0 \tag{47}$$

holds for all $z_i \geq 0$ if $\overline{\mu}$ is sufficiently large. Plugging (37) into (36) we obtain

$$\begin{aligned} \frac{\partial \Pi^{DF}}{\partial z_i} &= z_i \pi^D(z_i, t^{DF}) + (\overline{\mu} + z_i - z_j)\pi^D(z_i, t^{DF}) \\ &- (1-\delta)\tau z_j H(z_j, t^{DF}) - (\overline{\mu} + z_i - z_j) z_i \end{aligned}$$

Further differentiation yields the second-order condition

$$\frac{\partial^2 \Pi^{DF}(z_i, z^{DF})}{\partial^2 z_i} = 2\pi^D(z_i, t^{DF}) + \underbrace{\frac{\partial \pi^D}{\partial z_i}}_{=-1}(\overline{\mu} + 2z_i - z_j) - z_i - (\overline{\mu} + z_i - z_j) \tag{48}$$

Using (37) from which we obtain $\pi^D(z_i, t^{DF}) = \left(\frac{1-\epsilon}{2}\right)^2 - z_i$ and inserting this into (48) we obtain

$$\begin{aligned} \frac{\partial^2 \Pi^{DF}(z_i, z^{DF})}{\partial^2 z_i} &= 2\left[\left(\frac{1-\epsilon}{2}\right)^2 - z_i\right] - 2(\overline{\mu} + z_i - z_j) - z_i \\ &= -5z_i + 2\left[\left(\frac{1-\epsilon}{2}\right)^2 - \overline{\mu} + z_j\right] \end{aligned}$$

For (47) to hold for $z_i \geq 0$ it is sufficient to show that for sufficiently large $\overline{\mu}$ the following is true

$$\overline{\mu} > \left(\frac{1-\epsilon}{2}\right)^2 + z^{DF} \tag{49}$$

However, as z^{DF} itself depends on $\overline{\mu}$ we have to carry out some straightforward term rewriting. Define $D = \left(\frac{1-2\epsilon}{2}\right)^2 - \left(\frac{\epsilon}{2}\right)^2$. Then we have $B(\epsilon) = D - 2\overline{\mu}$ and (49) becomes

$$\begin{aligned}
& \overline{\mu} > \left(\frac{1-\epsilon}{2}\right)^2 + \frac{1}{2}(D - 2\overline{\mu} + \sqrt{(D-2\overline{\mu})^2 + (1-\epsilon)^2\overline{\mu}}) \\
\Leftrightarrow \quad & \left((2\overline{\mu} - D) + 2\left(\overline{\mu} - \left(\frac{1-\epsilon}{2}\right)^2\right)\right)^2 > (D-2\overline{\mu})^2 + (1-\epsilon)^2\overline{\mu} \\
\Leftrightarrow \quad & 12\overline{\mu}^2 - \overline{\mu}\left(4D + 16\left(\frac{1-\epsilon}{2}\right)^2 + (1-\epsilon)^2\right) > -4\left(\frac{1-\epsilon}{2}\right)^2\left[D + \left(\frac{1-\epsilon}{2}\right)^2\right]
\end{aligned}$$

which holds for all $\overline{\mu}$ that are sufficiently large. ∎

Proof of Lemma 3

Let $BR_i^{DNF}(z_j)$ be the best-response function for region i that is implicitly defined by (42). To prove the lemma we show that $BR_i^{DNF}(z^{DNF}) = z^{DNF}$. We will argue that $z_i = z^{DNF}$ is a global optimum of $\Pi(z_i, z^{DNF})|_{z_i \geq 0}$. Inspection of (41) shows that Π^{DNF} is a polynomial of degree four. As $\lim_{z_i \to -\infty} \Pi(z_i, z^{DNF}) = \lim_{z_i \to \infty} \Pi(z_i, z^{DNF}) = -\infty$ we know that it has two maxima and one minimum. One easily verifies that

$$2\frac{\partial \Pi^{DNF}}{\partial z_i}|_{z_i=0, z_j=z^{DNF}} = -(1-\delta)\tau\frac{(z^{DNF})^2}{1-\tau} < 0$$

so there can be at least two extrema of $\Pi^{DNF}(z_i, z^{DNF})$ on $z_i \geq 0$. We know that z^{DNF} is one of them. We need to rule out that it is the minimum under the assumption that $\overline{\mu}$ is sufficiently large. The following lemma establishes this result.

Lemma 7

$$\lim_{\overline{\mu} \to \infty} \frac{\partial^2 \Pi^{DNF}}{\partial^2 z_i}|_{z_i=z_j=z^{DNF}} < 0$$

Proof We have

$$\begin{aligned}
\frac{\partial^2 \pi^{DNF}}{\partial^2 z_i}|_{z_i=z_j=z^{DNF}} &= 4\pi^{DNF}(z^{DNF}, z^{DNF}) \\
&+ \overline{\mu}\frac{\partial \Pi^{DNF}}{\partial z_i}|_{z_i=z_j=z^{DNF}} - \frac{z^{DNF}}{(1-\tau)^2}
\end{aligned}$$

It is sufficient to show that $\frac{\partial \Pi^{DNF}}{\partial z_i}|_{z_i=z_j=z^{DNF}}$ is negative. We have

$$\frac{\partial \Pi^{DNF}}{\partial z_i}|_{z_i=z_j=z^{DNF}} = \frac{1}{1-\tau}(\delta\tau - \frac{z^{DNF}}{1-\tau}) < 0 \qquad (50)$$

$$\Leftrightarrow \quad z^{DNF} > \frac{\delta\tau(1-\tau)}{2} \qquad (51)$$

Let $C = \delta\tau(1-\tau)$. Then (51) implies

$$\begin{aligned} & \sqrt{A^2 + 8\overline{\mu}C} > C - A \\ \Leftrightarrow\ & 0 > C^2 - (2A + 8\overline{\mu})C \\ \Leftrightarrow\ & C < (2A + 8\overline{\mu}) \\ \Leftrightarrow\ & 0 < (3\delta - 2)\tau(1-\tau) + 2\overline{\mu} \end{aligned}$$

which holds for a sufficiently large $\overline{\mu}$ ∎

So z^{DNF} is at least a local maximum of $\Pi^{DNF}(z_i, z^{DNF})$ on $z_i \geq 0$. We still need to rule out the corner solution $BR_i^{DNF}(z^{DNF}) = 0$. To do this it is sufficient to show that

$$\Pi^{DNF}|_{z_i=z_j=z^{DNF}} - \Pi^{DNF}|_{z_i=0, z_j=z^{DNF}} > 0 \tag{52}$$

Equation (52) is equivalent to

$$\begin{aligned} & 2\overline{\mu}z^{DNF}\pi^{DNF}(z^{DNF}, z^{DNF}) + 2\overline{\mu}z^{DNF}(1-\delta)\tau\frac{z^{DNF}}{1-\tau} \\ - \ & 2(\overline{\mu} + z^{DNF})z^{DNF}(1-\delta)\tau\frac{z^{DNF}}{1-\tau} \\ = \ & 2\overline{\mu}z^{DNF}\pi^{DNF}(z^{DNF}, z^{DNF}) - 2z^{DNF}(1-\delta)\tau\frac{z^{DNF}}{1-\tau}z^{DNF} \end{aligned}$$

As $\pi^{DNF}(z^{DNF}, z^{DNF}) > 0$ (52) holds for sufficiently large $\overline{\mu}$. This completes the proof. ∎

Proof of Lemma 4

From (32) and (44) we have $z^{DNF} \geq z^{CNF}$ if and only if

$$\frac{4}{3}\tau - ((2\delta-1)\tau - \frac{3\overline{\mu}}{1-\tau}) \leq \sqrt{((2\delta-1)\tau - \frac{3\overline{\mu}}{1-\tau})^2 + \frac{8\overline{\mu}\delta\tau}{1-\tau}}$$

which is equivalent to

$$\frac{16}{9}\tau^2 - \frac{8}{3}\tau((2\delta-1)\tau - \frac{3\overline{\mu}}{1-\tau}) \leq \frac{8\overline{\mu}\delta\tau}{1-\tau} \tag{53}$$

$$\Leftrightarrow \frac{16}{9}\tau^2 + \frac{8\overline{\mu}\tau}{1-\tau}(1-\delta) - \frac{8}{3}\tau^2(2\delta-1) \leq 0 \tag{54}$$

$$\Leftrightarrow \frac{16}{9}\tau^2 + \frac{8\overline{\mu}\tau}{1-\tau}(1-\delta) - \frac{8}{3}\tau^2(2\delta-1) \leq 0 \tag{55}$$

$$\Leftrightarrow \delta^0(\overline{\mu}) \equiv \frac{\frac{5}{9}\tau + \frac{\overline{\mu}}{1-\tau}}{\frac{6}{9}\tau + \frac{\overline{\mu}}{1-\tau}} \leq \delta \tag{56}$$

We see that for all $\overline{\mu}$ there exists a δ^0 such that $z^{DNF} \geq z^{CNF}$ if and only if $\delta \geq \delta^0$. This proves the first part of the proposition. To see that $\delta^0(\overline{\mu}) \in [0, 5/6)$ note that for an extreme competition effect ($\overline{\mu} = 0$) we have $\delta^0(0) = 5/6$. Furthermore note that we have

$$\lim_{\overline{\mu} \to \infty} \delta^0(\overline{\mu}) = 1$$

For the second part of the lemma simply note that

$$\frac{\partial \delta^0}{\partial \overline{\mu}} = \frac{1}{9} \frac{\tau}{(6/9\tau + \overline{\mu}/(1-\tau))} > 0$$

This means that the parameter range for which decentralization dominates centralized decision making with respect to the number of students gets smaller as the competition effect becomes weaker. ∎

Proof of Lemma 2

Follows from $\frac{\partial z^{DF}}{\partial \epsilon} < 0$, $\frac{\partial z^{DF}}{\partial \overline{\mu}}|_{\epsilon=0} < 0$, $z^{DF}|_{\epsilon=1} = 0$ and $z^{DF}|_{\epsilon=0,\overline{\mu}=0} = 0.25 > z^{ZF} = 0.125$. The only non-trivial task is to show that $\frac{\partial z^{DF}}{\partial \overline{\mu}}|_{\epsilon=0} < 0$ holds. From (39) we obtain

$$z^{DF}|_{\epsilon=0} = 0.125 - \overline{\mu} + \sqrt{1/16 + 4\overline{\mu}^2}$$

We then have $\frac{\partial z^{DF}}{\partial \overline{\mu}}|_{\epsilon=0} = -1 + \frac{\overline{\mu}}{\sqrt{1/16+4\overline{\mu}^2}} < 0$. Note that it is easy to show that

$$\lim_{\overline{\mu} \to \infty} z^{DF}|_{\epsilon=0} = 0.125 = z^{ZF}$$

so for all $\overline{\mu}$ we have $\epsilon_0 \geq 0$. ∎

Proof of Lemma 6

We have $q^{DF} > q^{DNF}$ iff

$$\frac{1-\epsilon}{2} > \frac{z^{DNF}}{1-\tau}$$

$$\begin{aligned}
\Leftrightarrow \quad & ((1-\epsilon) - ((2\delta - 1) - \frac{3\overline{\mu}}{1-\tau}))^2 > ((2\delta - 1) - \frac{3\overline{\mu}}{1-\tau})^2 + \frac{8\overline{\mu}\delta\tau}{1-\tau} \\
\Leftrightarrow \quad & (1-\epsilon)^2 - 2(1-\epsilon)((2\delta-1)\tau - \frac{3\overline{\mu}}{1-\tau}) > \frac{8\overline{\mu}\delta\tau}{1-\tau} \\
\Leftrightarrow \quad & (1-\epsilon)^2 - 2(1-\epsilon)(2\delta-1)\tau > \frac{\overline{\mu}}{1-\tau}(2\delta\tau - 6(1-\tau)))
\end{aligned}$$

Then we have

$$\frac{\partial LHS}{\partial \tau} = -2(1-\epsilon)(1-\delta) < 0$$

$$\frac{\partial RHS}{\partial \tau} = \frac{2\delta}{1-\tau} > 0$$

Furthermore $\lim_{\tau \to 1} RHS = \infty$ $\blacksquare$

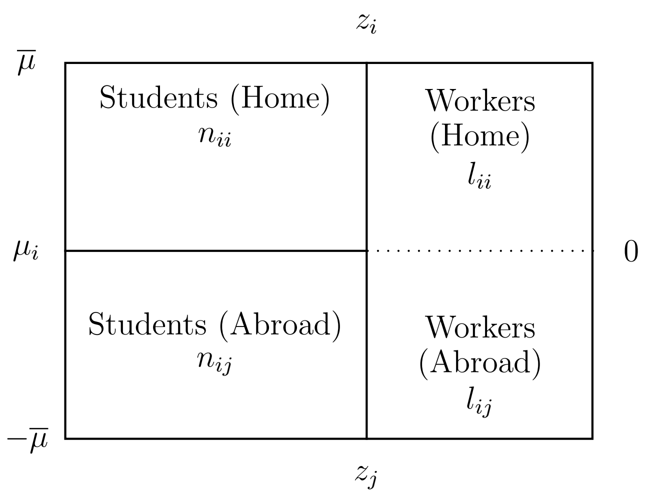

Figure 2: Occupational and locational choice of individuals in region i when tuition fees and quality are identical for both regions

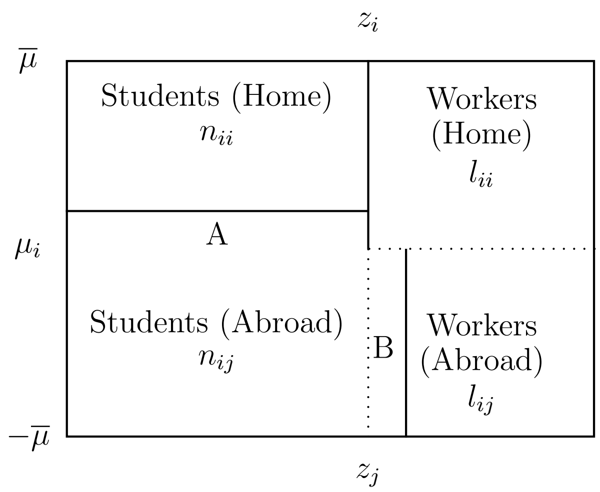

Figure 3: Reaction of occupational and locational choice in region i to an increase Δz_j of z in region j

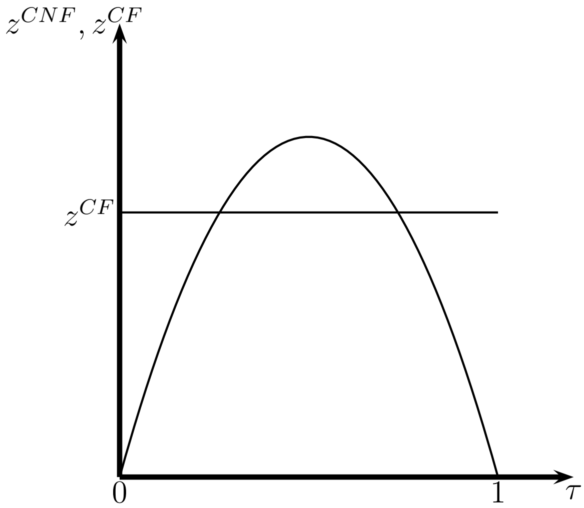

Figure 4: The net-income of students under centralization in dependence of τ.

B Derivation of selected results

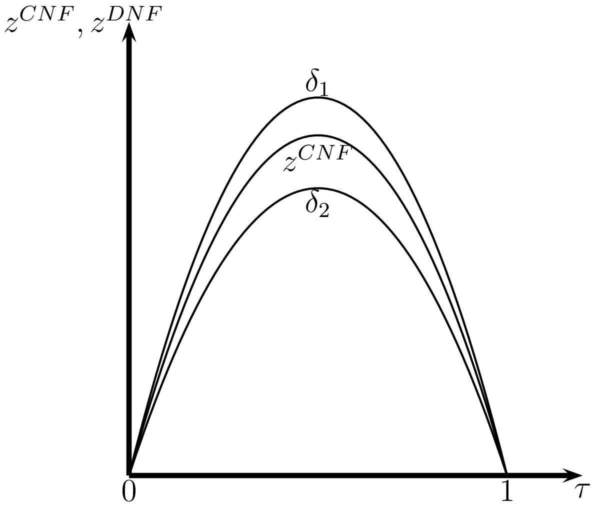

Figure 5: The net-income of students under decentralization in dependence of τ for different levels of δ; i.e. $\delta_1 > \delta^0 > \delta_2$. We see that higher δ leads to more students for all levels of τ.

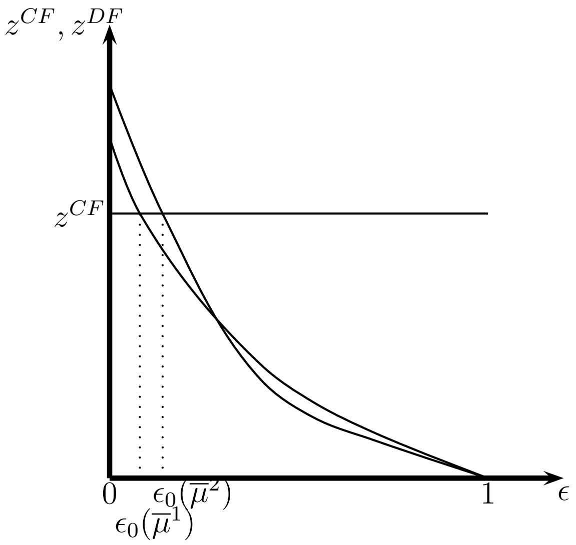

Figure 6: Equilibrium net-student income z under decentralization for different parameters $\overline{\mu}^2 < \overline{\mu}^1$

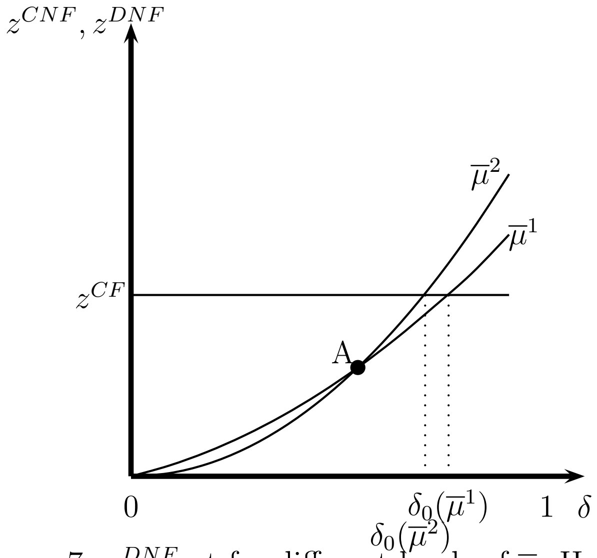

Figure 7: z^{DNF} at for different levels of $\overline{\mu}$. Here $\overline{\mu}^2 < \overline{\mu}^2$.