Funding, Competition and Quality in Higher Education

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Abstract

This paper explores the impact of university finance reforms on teaching quality. It is shown that the graduate tax can achieve efficiency with tuition fees administered by the government, while student grants, pure and income contingent loans are bound to fail. All options are inefficient when universities have the autonomy to set tuition fees. Then, pure loans dominate the graduate tax and are more efficient than income contingent loans unless peer group effects are strong. However, properly chosen uniform administered fees create an even higher surplus. Moreover, pure loans may make the majority of students worse off than a central assignment system with very poor quality incentives.

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1 Introduction

In both popular and academic discussion, much of the sluggishness and uncompetitiveness of European higher education is perceived as a lack of proper incentives. This argument applies to both students and university authorities: While free access to universities induces too many people to take up a study, tight regulations often prevent university competition for teaching excellence.

In accordance with general economic theory, the source of inefficiency is ascribed to missing markets or price mechanisms. Therefore, market-oriented reforms, like the introduction of tuition fees, are gaining more and more ground in the policy debate.[1] The beneficial effects promised by tuition fees are twofold: On the one hand, they contribute to the efficiency of enrolment choices by confronting students with at least some of the real cost of their study.[2] On the other hand, they may establish a closer link between university revenue and student attendance, which enhances competition with respect to teaching quality. Of course, this holds only when tuition payments do not vanish in the general government budget but accrue directly to universities. Hence, tuition fees are often demanded to be combined with more university autonomy, in particular the ability to charge and keep fees in the amount desired.[3]

Maybe surprisingly, the literature has shown quite little concern with the issue of university competition, apart from the general critique of applying standard economic theory to education (Winston, 1999, Franck and Schönfelder, 2000). Del Rey (2000) investigates the strategic choice of universities between teaching and research activities, focussing on how the final allocation can be controlled by a proper choice of the governments' parameters. De Fraja and Iossa (2002) explore how strategic admission setting can lead to quality differentiation between higher education institutions. While these two approaches take the standard financing scheme of a lump sum transfer plus a

1 In fact, a number of countries, like the UK, have introduced fees in recent years, while the discussion becomes increasingly intense in other countries like Germany (Greenaway and Haynes, 2003, Jahresgutachten, 1998/1999).

2 See, e.g. Garcia-Peñalosa and Wälde (2000). However, when individuals display decreasing absolute risk aversion, tuition fees may not achieve full efficiency due to too low or wealth-biased educational choice (Wigger and von Weizsäcker, 2001, De Fraja, 2001).

3 See, for the UK, Greenaway and Haynes (2003). In Germany, extending university autonomy is advocated, e.g., by the German Council of Economic Advisors (Jahresgutachten, 1998/1999). This is not to deny that there are a number of other arguments for abandoning the traditional system of the general taxpayer subsidizing students, the most prominent one being the reverse redistribution implied by such a scheme (Hansen and Weisbrod, 1969). However, this is not undisputed (Sturn and Wohlfahrt, 2000).

per student grant as given, this paper tackles the question how various popular reform proposals (pure loan schemes, graduate taxes, income contingent loans) affect the competition between universities and thus the quality of teaching activities.[4] Moreover, unlike the two above-mentioned approaches, we also explore the welfare consequences of higher education finance.

The analysis leads to the following results. First, efficiency in higher education is shown to require some differentiation of teaching qualities, with the more able enjoying higher quality. Second, uniform tuition fees determined by the government are inefficient and exhibit no difference to the standard financing scheme when students are given free enrolment choice. Third, if fees are administered, but differentiated, the graduate tax system is capable of implementing the surplus maximizing solution for a proper choice of policy instruments whereas all other considered schemes fail to achieve efficiency. Fourth, university autonomy is an important factor when assessing the impact of the reform proposals. Letting universities compete in terms of quality and tuition fees makes the pure loan scheme preferable to the graduate tax on efficiency grounds, although quality differentiation is excessive. Fifth, we find the strategic interaction between autonomous universities to exert adverse effects on both students and the economy as a whole in the sense that properly chosen uniform administered fees lead to a higher social surplus than either considered reform option. On top of that, we show that the pure loan scheme under university autonomy can make the vast majority of students worse off than a highly regulated system under which universities have very poor incentives for quality provision.

The paper is organized as follows. Having laid out the basics of the model and the efficient solution in section 2, section 3 investigates the working of centralized student grant systems. Section 4 introduces tuition fees, administered by the government. Section 5 derives the effects under university autonomy. We conclude in Section 6.

2 Basics of the Model

Consider a society populated by a number of individuals/students with their total mass normalized to 1, born with the same basic productivity, which we also normalize to

4 See Barr (1993) for a general overview of alternative financing schemes. Boadway, Marchand and Marceau (1996) address a related question in the context of secondary education. However, that model differs significantly from the present one, as it incorporates both quality and location issues, neglects ability differences and concentrates on the introduction of education vouchers.

1. However, people differ with respect to their learning capabilities, measured by the probability of graduating from university $\theta \in [0, 1]$. For convenience, we assume that abilities follow a uniform distribution: $f(\theta) = 1$.

All individuals live for two periods. In the first period of life, individuals either start working straight away, earning an income of 1 in either period or take up a study lasting for one period. However, there exists an exogenous admission standard: only those students with ability of at least $\underline{\theta}$ are allowed to go to university. Without loss of generality, we neglect discounting.

University attendance has a twofold effect on individual earnings. On the one hand, the productivity of a graduate increases by q, the teaching quality offered by the respective university. On the other hand, mere university attendance augments individual earnings. This increase, which max be due to network effects or the fact that even those who fail have learned something, amounts to ξ and is enjoyed by all students. Thus, the expected gross income from going to university is:[5]

$$\theta(\xi + q) + (1 - \theta)\xi = \xi + \theta q. \tag{1}$$

In what follows, ξ is assumed to be so high that all admitted students prefer to attend university for all equilibrium constellations of qualities and tuition fees, a restriction to be discussed in the conclusions section. Thus, like in Del Rey (2000), the total number of students is constant.

There are two universities, $i = 1, 2$, engaged in both teaching and research activities. Basically, universities are interested in the reputation from research activities only. However, according to the Humboldtian perception of synergies between teaching and research activities, the total productivity of students spills over on research productivity.[6] Thus, the target of universities is to maximize the rents from research:

$$\pi_i = R_i + \alpha q_i N_i, \tag{2}$$

where R_i is the research budget and α measures the strength of the spillover.[7]

5 We assume that students are risk-neutral, thereby eliminating any wealth biases with respect to enrolment choices (De Fraja, 2001). The implications of allowing for risk-aversion are discussed in the Conclusions section.

6 Of course, research activities spill over on teaching quality as well. Therefore, (2) should be considered as a reduced form of these interrelations.

7 The incorporation of total teaching quality in universities' objectives could of course also be justified by a desire to obtain reputation from teaching excellence as well. However, in terms of later interpretation, we stick to the spillover interpretation.

While one unit of research is assumed to consume just one unit of financial resources, the cost of teaching N_i students with average success probability $\bar{\theta}_i$ at a quality q_i is:

$$c(q_i, N_i, \bar{\theta}_i) = [\gamma q_i^2 - \beta\bar{\theta}_i]N_i, \quad \alpha, \beta, \gamma > 0. \tag{3}$$

Thus, the direct teaching cost $\gamma q_i^2 N_i$ is strictly convex. However, students are not only clients, but also inputs for university services (Rothschild and White, 1995). Therefore, a higher average ability of students reduces the resources necessary to accomplish a given quality level.

Despite its' very simple structure, the model leads to a wealth of cases to be considered. In order to present the main results as clear as possible, we impose some restrictions on the parameters: First, the research-teaching tradeoff is severe in the sense that research funds matter for universities always at least as much as total teaching quality does: $\alpha \in [0, 1]$.[8] Second, the cost reducing peer group effect has an upper bound ensuring that per capita teaching costs are always positive: $\beta < \alpha^2/(4\gamma) \leq 1/(4\gamma)$.[9] And third, the admission standard is high enough to rule out corner solutions with respect to quality choices: $\underline{\theta} > (1 + 4(\alpha - \beta\gamma))/5$. Each of these restrictions is in fact stronger than needed for the following results to hold.

As a benchmark, we now derive the efficient solution, which maximizes the surplus or sum of utilities generated in the sector of higher education. In case it becomes optimal to have both universities offering differing teaching qualities, we will call university 1 the high- and university 2 the low-quality university: $q_1 \geq q_2$. Denoting the type generating the same marginal surplus in either university by $\hat{\theta}$, the problem is to maximize:

$$\begin{aligned} S &= \int_{\underline{\theta}}^{\hat{\theta}} (\xi + \theta q_2)d\theta + (\alpha q_2 - \gamma q_2^2)(\hat{\theta} - \underline{\theta}) + \beta\frac{\hat{\theta} + \underline{\theta}}{2} \\ &\quad + \int_{\hat{\theta}}^{1} (\xi + \theta q_1)d\theta + (\alpha - \gamma q_1^2)(1 - \hat{\theta}) + \beta\frac{1 + \hat{\theta}}{2}, \end{aligned} \tag{4}$$

8 A quite similar assumption is made by Del Rey (2000), see her Propositions 2, 4, and 6.

9 As is shown below, the teaching-research spillover ensures that universities choose a teaching quality of at least $\alpha/(2\gamma)$. When only the most able student attends such an institution ($\bar{\theta}_i = 1$), per capita cost become $\alpha^2/(4\gamma) - \beta$, which is positive only under the above restriction on β.

with respect to $q_1, q_2, \hat{\theta}$.[10] This leads to the first order conditions:

$$(1-\hat{\theta}^2)/2 + (\alpha - 2\gamma q_1)(1-\hat{\theta}) = 0 \tag{5}$$

$$(\hat{\theta}^2 - \underline{\theta}^2)/2 + (\alpha - 2\gamma q_2)(\hat{\theta} - \underline{\theta}) = 0 \tag{6}$$

$$\hat{\theta}(q_1 - q_2)[-\alpha + \gamma(q_1 + q_2)] = 0. \tag{7}$$

Proposition 1. *The efficient solution entails a differentiation of teaching qualities according to ability: The brighter half of students ($\theta \geq \theta^* = (1+\underline{\theta})/2$) should attend university 1 with quality $q_1^* = (3+\underline{\theta}+4\alpha)/(8\gamma)$, while the less able students ($\theta < \theta^*$) should receive the lower quality $q_2^* = (1+3\underline{\theta}+4\alpha)/(8\gamma)$ at university 2.*

PROOF. Follows immediately from solving (5)-(7). □.

The reason behind the differentiation of teaching qualities is straightforward. Investments in high ability students generate a higher expected return, as these people are less likely to fail.[11] It should be noted that quality differentiation is not a consequence of the existence of peer group effects. In fact, these effects cancel out at the aggregate level – the gain in total productivity by one university is just offset by the loss of the other – and have no impact on the equilibrium, apart from the maximum level of surplus:

$$S^* = (1-\underline{\theta})\left[\xi + \frac{\alpha(1+\underline{\theta}+\alpha)}{4\gamma} + \frac{\beta(1+\underline{\theta})}{2}\right] + \frac{(1-\underline{\theta})[5+6\underline{\theta}+5\underline{\theta}^2]}{64\gamma}.$$

3 Student grants

In many OECD countries, the university sector is more or less monopolized by the state and subject to numerous regulatory constraints. With respect to funding, governments rely predominately on state financed student grants paid out directly to universities (Fausto, 2002). While the precise fund allocating mechanisms vary among countries, a scheme with universities receiving a per-student grant t and a general budget B can be considered a reasonable approximation (DelRey, 2001, De Fraja & Iossa, 2002). Like

10 Marginal costs and benefits of research are constant and equal, so the optimal research budget is indeterminate and thus omitted. This allows us to focus entirely on the problems of the quality of higher education. Of course, the presence of societal benefits of research might make some diversion of teaching expenditures attractive when sufficient research funds are lacking. While correct in the present model, such a reasoning would however ignore the problems of shirking or diversion of funds towards non-productive activities.

11 Therefore, a random assignment of students with differing success probabilities among two universities providing different qualities must be inefficient.

Garcia-Peñalosa & Wälde (2000), we assume that funds are financed by a lump-sum tax T.[12] In addition to financing schemes, some countries impose also tight regulations on student access to universities. In Germany, e.g., students of most subjects have to apply at a central authority to be assigned to universities according to a number of criteria. In the context of this model, such a central assignment system implies: $N_1 = N_1^{CA}, N_2 = N_2^{CA}$ with average success probabilities $\bar{\theta}_1^{CA}, \bar{\theta}_2^{CA}$.

This high degree of regulation nonwithstanding, universities can hardly be monitored perfectly with respect to all spending decisions. There are vivid every-day examples of this leeway to be observed in academic life, like the time spent for preparing lectures, staff teaching loads or the type and number of books ordered for the library. We do not develop a detailed principal-agent setup here, but simply assume that universities are capable of choosing any non-negative quality level desired: $q_i \geq 0$. This means that the research rent (2) consists of two parts: the general budget B and the net rents from diversion $(t + \alpha q_i - \gamma q_i^2 + \beta\bar{\theta}_i)N_i$ with the term in brackets being referred to as r_i, the per student rent earned by university i.

Obviously, the central assignment scheme fails to achieve efficiency in such a setting: Maximizing $\pi_i^{CA} = B + (t + \alpha q_i - \gamma q_i^2 + \beta\bar{\theta}_i^{CA})N_i^{CA}$ with respect to q_i leads immediately to $q_i^{CA} = \alpha/2\gamma$. Thus, either university spends $\alpha^2/(4\gamma)N_i^{CA}$ on teaching due to its research-enhancing effects. However, all further resources are diverted towards research, leading to an inefficiently low surplus of:[13]

$$S^{CA} = (1 - \underline{\theta}) \left[\xi + \frac{\alpha(1 + \underline{\theta} + \alpha)}{4\gamma} + \frac{\beta(1 + \underline{\theta})}{2} \right] < S^*,$$

provided that total funds are high enough to finance q_i^{CA}. For the purpose of later comparisons, we assume that the government chooses the per capita grant just such as to cover these teaching expenditures: $t^{CA} = \alpha^2/(4\gamma)$.

The inefficiency of the central assignment system is an immediate consequence of lacking incentives to attract students on part of universities. Therefore, a promising alternative to central assignment is to allow students the free choice between universities. Prospective students decide according to a comparison of expected net incomes $\theta(\xi + q_i) - T$, which leads to the application pattern:

12 In addition to keeping the analysis simple, this assumption constitutes a convenient way to capture the well-reported reverse effect on the distribution of lifetime income distributions due to high income earners (the graduates) being subsidizes by the average taxpayer with a lower income.

13 In a sense, this finding mirrors the popular complaints about poor teaching quality in state-run university systems. However, it should be stressed, that universities indeed divert resources from the research budget in order to maintain the desired teaching qualities when teaching is underfunded ($t < \alpha^2/(4\gamma)$).

$$N_i = \begin{cases} 1-\underline{\theta} & : \quad q_i > q_j \\ (1-\underline{\theta})/2 & : \quad q_i = q_j \\ 0 & : \quad q_i < q_j \end{cases} . \tag{8}$$

All students either attend the higher quality institution or are indifferent between both offers and enrol randomly. Thus, the average student ability amounts in either case to $\bar{\theta}_i = (1+\underline{\theta})/2$ and the target of university i becomes to maximize $B + (t + \alpha q_i - \gamma q_i^2 + \beta\bar{\theta}_i)N_i$ with respect to q_i, with N_i given by (8). This leads to the reaction function:

$$q_i(q_j) = \begin{cases} \alpha/(2\gamma) & : \quad q_j < \alpha/(2\gamma) \\ q_j + \varepsilon & : \quad \alpha/(2\gamma) \leq q_j < \hat{q}(t, (1+\underline{\theta})/2) \\ q \leq \hat{q} & : \quad q_j = \hat{q}(t, (1+\underline{\theta})/2) \\ q \leq q_j - \varepsilon & : \quad q_j > \hat{q}(t, (1+\underline{\theta})/2) \end{cases} , \tag{9}$$

where

$$\hat{q}(t, \bar{\theta}_i) = \frac{\alpha}{2\gamma} + \sqrt{\frac{\alpha^2 + 4\gamma t + 4\beta\gamma\bar{\theta}_i}{4\gamma^2}}, \tag{10}$$

denotes the quality level equalizing the grant t and the net per student loss in research funds when average ability is $\bar{\theta}_i$. Provided that both institutions choose at least the minimum quality levels $\alpha/(2\gamma)$, each university is eager to attract all students by just excelling the quality provided by the competitor, unless the net per student loss exceeds the grant. As a consequence, universities find themselves in a tight Bertrand-like competition with equilibrium teaching qualities:

$$q_1^{SC}(t) = q_2^{SC}(t) = \hat{q}(t, (1+\underline{\theta})/2) \tag{11}$$

where we suppress the average student quality, identical for both institutions, for ease of notation. Free student choice establishes a link between financial rewards and teaching performance, and thus improves equilibrium teaching quality, compared to central assignment. Moreover, it precludes any diversion of teaching funds for research purposes. However, the maximum surplus that can be attained by this scheme is inefficiently low: maximizing (4) with respect to t, taking (11) into account, yields the optimal grant $t^{FC} = \frac{(1+\underline{\theta})^2 - 4\alpha^2 + 8\beta\gamma(1+\underline{\theta})}{16\gamma}$, teaching quality $q^{FC} = (2\alpha + 1 + \underline{\theta})/(4\gamma)$ and the surplus:

$$S^{FC} = S^{CA} + \frac{(1-\underline{\theta})[4 + 8\underline{\theta} + 4\underline{\theta}^2]}{64\gamma},$$

which is lower than S^*. This inefficiency arises because the tight competition induces both universities to offer identical teaching qualities, ruling out efficient differentiation and student sorting.

4 Tuition fees

As argued in the Introduction, tuition fees are often considered as tools superior to bureaucratic formula funding. However, in a world with poor availability of private educational loans, the mere introduction of a price to be paid for university services creates problems of inefficiencies and injustices due to social and/or wealth biases in demand. To compensate for this, some pre-financing of tuition fees must be provided.

The recent discussion about university finance reform is dominated by three reform proposals, as summarized by Garcia-Penalosa & Wälde (2000): the pure loan scheme, the graduate tax and income contingent loans. Under either alternative, students receive a governmental loan covering the fee f_i to be repaid later during working life. However, significant differences arise with respect to repayment facilities. The pure loan scheme requires students to pay back their loan irrespective of educational success, which in the present model implies an expected income of $\xi + \theta q_i - f_i$. The graduate tax scheme, in contrast, subsidizes some part ρ of educational costs, to be financed by a tax T^{GT} on the successful students only. Expected lifetime income is thus $\xi + \theta(q_i - T^{GT}) - (1-\rho) f_i$. Thence, the pure loan scheme is equivalent to a graduate tax with the subsidy set to zero. Income contingent loans, however, relieve unsuccessful students from any repayment and cover the resulting deficit by a general tax, so expected earnings are: $\xi + \theta(q_i - f_i) - T^{IC}$.

When tuition fees are uniform ($f_1 = f_2$), all three options yield identical results in terms of teaching qualities, which is due to the equivalence of enrolment patterns. Comparing the lifetime incomes generated by attending either university, students behave according to:

$$N_i = \begin{cases} 1 - \underline{\theta} & : \quad q_i > q_j \\ (1 - \underline{\theta})/2 & : \quad q_i = q_j \\ 0 & : \quad q_i < q_j \end{cases} .$$

As attendance costs are effectively the same at both universities, enrolment is determined by quality differences only. Thus, choices are equivalent to (8), and tuition fees replicate the equilibrium under free students' choice and a per capita grant f. As a consequence, uniform tuition fees do not create any efficiency gains compared to free student choice by strengthening university competition. Moreover, uniform fees can not create the diversity required by the efficient solution. A prerequisite for this to happen would be to charge differentiated fees $f_1 \geq f_2$. Differentiated grants, however, can not create any efficiency gains as students' enrolment decisions continue to be determined by quality differences alone. Therefore, any superiority of tuition fees in this model is grounded in the possibility to differentiate prices.

With non-uniform tuition fees, the enrolment patterns differ among alternatives. Under the pure loan scheme, the student indifferent between attending university 1 and 2 is characterized by $\tilde{\theta}(1+q_1) - f_1 = \tilde{\theta}(1+q_2) - f_2$, so:

$$\tilde{\theta}^{PL} = \frac{f_1 - f_2}{q_1 - q_2}. \tag{12}$$

All students with a higher success probability attend university 1: $N_1^{PL} = 1 - \tilde{\theta}^{PL}$ while the less able visit university 2: $N_2^{PL} = \tilde{\theta}^{PL} - \underline{\theta}$. A similar pattern emerges for the graduate tax, where:

$$\tilde{\theta}^{GT} = \frac{(1-\rho)(f_1 - f_2)}{q_1 - q_2}. \tag{13}$$

If instead, students receive income contingent loans, their enrolment decision depends only on the earnings-fee differential in case of success:

$$N_i^{IC} = \begin{cases} 1 - \underline{\theta} & : \quad q_i > q_j - f_j + f_i \\ (1 - \underline{\theta})/2 & : \quad q_i = q_j - f_j + f_i \\ 0 & : \quad q_i < q_j - f_j + f_i \end{cases}. \tag{14}$$

Proposition 2. *With centrally administered tuition fees, neither pure nor income contingent loans implement the efficient solution. Efficiency can be achieved under the graduate tax scheme for a proper choice of differentiated fees and the subsidy rate.*

The formal derivation of this proof is a little involved and therefore relegated to the Appendix. The economic intuition behind this result is as follows. Efficiency requires a differentiation of qualities with attendance sorted according to ability. However, by (14), any equilibrium with positive attendance at both universities under income contingent loans must leave all students indifferent between both institutions. With students being distributed by chance, efficient sorting can not result.[14] The inefficiency of pure loans lies in the dual task of tuition fees: on the one hand, they must ensure efficient teaching by rewarding universities with the marginal social benefit of enhancing quality. On the other hand, they must induce efficient sorting of students by equalizing absolute private benefits across universities for the particular student type. These two tasks are not perfectly aligned, making it impossible to achieve efficiency with respect to all three variables of the model by just two instruments. This problem can not be

14 However, as shown in the appendix, income contingent loans lead almost never to efficiency even if efficient sorting occurred. That failure can be attributed to the same reason that makes pure loans inefficient.

resolved by simply assigning students to universities, as this would destroy universities' teaching incentives. However, the graduate tax scheme has this one more instrument available to correct for students' choices, namely the subsidy rate.

5 University Autonomy

The above efficiency property of graduate taxes hinges crucially on the proper choice of fees and the subsidy by a benevolent central authority. Therefore, this section addresses the question to what extent the efficient solution can be decentralized by giving universities more autonomy, in particular the right to set tuition fees. Thus, we now consider settings in which universities are free to choose both qualities and fees. In order to capture the strategic interactions involved in full, we assume that universities anticipate the influence of their quality choices on fee setting possibilities. This means that in fact a three stage game is solved: at stage 1, universities announce their teaching qualities. Then, at stage 2, they announce the respective tuition fees. Finally students decide on which university to attend at stage 3. As the analysis becomes a little bit more involved, we derive the equilibria under either proposal one after another.

5.1 Pure Loans

Under the pure loan scheme, students enrol according to (12) at stage 3. Taking this behavior into account, universities choose tuition fees in order to maximize $\alpha q_i N_i + B + (f_i + \beta\bar{\theta}_i^{PL} - \gamma q_i^2)N_i$ at stage 2, which gives the first-order conditions:

$$\frac{\partial \pi_i}{\partial f_i} = N_i^{PL} + (\alpha q_i + f_i + \beta\bar{\theta}_i^{PL} - \gamma q_i^2)\frac{\partial N_i^{PL}}{\partial f_i} + \beta\frac{\partial \bar{\theta}_i^{PL}}{\partial f_i}N_i^{PL} = 0. \tag{15}$$

When deciding on the level of fees, universities trade off the following three effects: first, they receive a higher contribution from each student attending the university. Second, they lose students to the competitor. This loss is the more severe, the more average ability matters. However, the wider the gap in teaching qualities (the larger $q_1 - q_2$), the smaller the loss in enrolment: $\frac{\partial N_i}{\partial f_i} = -1/(q_1 - q_2)$, because fees become less decisive for students, the more university qualities differ. Third, due to the impact on average ability, losing the marginal applicant decreases the quality cost for university 1, but decreases it for university 2.

As $\frac{\partial N_i^{PL}}{\partial f_i} = -\frac{\partial \hat{\theta}}{\partial f_i}$:

$$\bar{\theta}_i^{PL} \frac{\partial N_i^{PL}}{\partial f_i} + \frac{\partial \bar{\theta}_i^{PL}}{\partial f_i} N_i^{PL} = -\hat{\theta} \frac{\partial \hat{\theta}}{\partial f_i},$$

hence solving (15) for f_i as a function of qualities and the marginal student type gives:[15]

$$f_i = \gamma q_i^2 + \alpha q_i + N_i^{PL}(q_1 - q_2) - \beta \hat{\theta}^{PL}. \tag{16}$$

Inspection of (16) reveals that the peer group effect has a quantitatively identical impact on tuition fees which stems from its purely redistributional nature in the aggregate. The negative sign of the effect of β on f_2 is straightforward: both the loss in students and the deterioration of average ability become more important. For university 1, however, the positive effect on per capita quality cost is dominated by the loss of applicants.

Calculating the resulting fee differential:

$$f_1 - f_2 = \gamma(q_1^2 - q_2^2) + \alpha(q_1 - q_2) + (q_1 - q_2)(1 - 2\hat{\theta}^{PL} - \underline{\theta}),$$

dividing by $(q_1 - q_2)$ and solving for the indifferent student type yields:

$$\hat{\theta}^{PL}(q_1, q_2) = \frac{1 - \alpha + \underline{\theta} + \gamma(q_1 + q_2)}{3}, \tag{17}$$

an expression independent of β due to its identical effect on both fees. However, enrolment at university 1 depends negatively on either teaching quality. This holds because the direct quality cost function is strictly convex: When both qualities double, the fee differential widens as university 1 has to compensate a relatively higher cost increase than university 2. Thus, the marginal student type must be characterized by a higher success probability.

Inserting (17) into (16) leads to the following equilibrium fees:

$$\begin{aligned} f_1(q_1, q_2) &= \frac{(2 - \underline{\theta})(q_1 - q_2) + \beta\gamma(q_1 + q_2) - \alpha(2q_1 + q_2) + \gamma(2q_1^2 + q_2^2) - \beta(1 + \underline{\theta} - \alpha)}{3}, \\ f_2(q_1, q_2) &= \frac{(2 - \underline{\theta})(q_1 - q_2) + \beta\gamma(q_1 + q_2) - \alpha(q_1 + 2q_2) + \gamma(q_1^2 + 2q_2^2) - \beta(1 + \underline{\theta} - \alpha)}{3}, \end{aligned}$$

and per student rents:

$$\begin{aligned} r_1^{PL}(q_1, q_2) &= [2(q_1 - q_2) + \beta] N_1^{PL}(q_1, q_2)/2 \qquad (18) \\ r_2^{PL}(q_1, q_2) &= [2(q_1 - q_2) - \beta] N_2^{PL}(q_1, q_2)/2, \qquad (19) \end{aligned}$$

15 It should be stressed that these expressions define tuition fees only as implicit functions because $\hat{\theta}^{PL}$ depends on fees as well. However, this kind of exposition allows for a much clearer presentation of the effects shaping the stage-2 equilibrium, rather than solving for f_I explicitly.

which are increasing in the strength of peer group effects for university 1, but decreasing for university 2. Moreover, rents depend positively on the quality differential as it diminishes the sensitivity of enrolment decisions.

This dependency creates a structural difference in the objectives of universities at stage 1. Inserting the above values into the target functions yields:

$$\begin{aligned}\pi_1 &= B + [2(q_1 - q_2) + \beta]\frac{(2 - \underline{\theta} + \alpha - \gamma(q_1 + q_2))^2}{18}\\ \pi_2 &= B + [2(q_1 - q_2) - \beta]\frac{(1 - 2\underline{\theta} - \alpha + \gamma(q_1 + q_2))^2}{18}.\end{aligned}$$

At this stage, universities balance the effects of increasing quality on enrolment on the one hand and on research rents on the other hand. However, the signs of these effects differ between institutions as shown by the first order conditions:

$$\frac{\partial \pi_1}{\partial q_1} = (2 - \underline{\theta} + \alpha - \gamma(q_1 + q_2)) - 2(\beta + \gamma(q_1 - q_2)) = 0, \tag{20}$$

$$\frac{\partial \pi_2}{\partial q_2} = (1 - 2\underline{\theta} - \alpha + \gamma(q_1 + q_2)) + 2(\gamma(q_1 - q_2) - \beta) = 0. \tag{21}$$

Proposition 3. *The pure loan scheme leads to a differentiation of teaching qualities and tuition fees in equilibrium. However, they generate a suboptimal social surplus: While the quality offered by university 2 is inefficiently low, university 1 may provide an inefficiently high or low quality. Moreover, the sorting of students is distorted towards university 1.*

Proof. From (16), (17), (20) and (21):

$$\begin{aligned}[q_1^{PL}, q_2^{PL}] &= \left[\frac{5 - \underline{\theta} + 4(\alpha - \beta\gamma)}{8\gamma}\ ,\ \frac{5\underline{\theta} - 1 + 4(\alpha - \beta\gamma)}{8\gamma}\right]\\ [f_1^{PL}, f_2^{PL}] &= \left[\frac{49 + 16\alpha^2 - 58\underline{\theta} + 25(\underline{\theta})^2}{64\gamma} - \frac{\beta(168 + 120\underline{\theta} - 112\beta\gamma)}{192},\right.\\ &\qquad \left.\frac{25 + 16\alpha^2 - 58\underline{\theta} + 49(\underline{\theta})^2}{64\gamma} - \frac{\beta(168 + 120\underline{\theta} - 112\beta\gamma)}{192}\right],\\ [N_1^{PL}, N_2^{PL}] &= \left[\frac{1 + \underline{\theta}}{2} + \frac{\beta\gamma}{3}\ ,\ \frac{1 + \underline{\theta}}{2} - \frac{\beta\gamma}{3}\right].\end{aligned}$$

Comparing these values with the efficient solution reveals immediately that $q_2^{PL} < q_2^*$, while $q_1^{PL} \gtreqless q_1^* \iff \beta \lesseqgtr (1 - \underline{\theta})/(2\gamma)$. Moreover, $N_1^{PL} > N_1^*$ whenever $\beta > 0$. The total surplus of the pure loan scheme under university autonomy amounts to:

$$S^{PL} = S^{CA} + \frac{(1 - \underline{\theta})[1 + 14\underline{\theta} + \underline{\theta}^2]}{64\gamma} - \frac{\beta^2\gamma(1 - \underline{\theta})}{24}.\square.$$

This equilibrium has a familiar interpretation in terms of the maximum differentiation principle known from the vertical product differentiation literature (Shaked and Sutton, 1982). The more similar the qualities offered by both universities, the fiercer is the fee competition: when both universities offer the same quality, only the one with the slightly lower fee will attract all students. To avoid this, both universities differentiate with respect to teaching qualities. This allows them to charge higher tuition fees which creates a per student rent to be diverted towards research.

An increase in the strength of peer group effects has the following two interesting implications. First, while the absolute quality differential remains unaffected, lower qualities are offered in equilibrium. This holds because the tuition fees that can be charged for any given quality combination lower tuition decrease, see (16). While this aggravates the inefficiency of the low quality institution, it diminishes the incentives for university 1 to provide excessive teaching quality. Therefore, while the quality differential is unambiguously to high from the perspective of efficiency, underprovision of quality on part of both universities can result. This stands in contrast to the usual findings of the above cited literature. Second, peer group effects distort the enrolment decision towards the high quality institution. Again, this can be traced back to the strict convexity of the direct quality cost. A decrease of both qualities by the same amount, due to a higher β, generates higher cost savings and hence a higher fee reduction for university 1 than for university 2. As $q_1^{PL} > q_2^*$, all students with success probabilities $\theta \in (\hat{\theta}^* - \frac{\beta\gamma}{3}, \hat{\theta}^*)$ enjoy an inefficiently high teaching quality .

Turning to a comparison with alternative financing schemes, we find

Proposition 4. *The pure loan scheme with university autonomy leads to a higher social surplus than central assignment. However, some or even all students may be better off under central assignment.*

Proof. See Appendix.

This result highlights that the efficiency gains arising from the implementation of the pure loan scheme are very unequally distributed. In particular, the low ability students are affected: one the one hand, they face a higher financing burden, on the other hand, the quality improvement is weak or even negative: $q_2^{PL} > q^{CA}$ requires $\underline{\theta} < 1/5 + 4/5(\alpha - \beta\gamma)$. This happens when student heterogeneity is high, as this strengthens the incentives to differentiate, implying deteriorating quality and increasing fees at university 2.[16] However, this is mitigated by the existence of peer group

16 In fact, it can be demonstrated that the utility decrease of low ability students is not driven by alleviating the general taxpayer from higher education finance. When $\alpha = 0$, central assignment

effects decreasing tuition fees.

Proposition 5. *Optimally administered uniform fees make universities worse and students as a whole better off than pure loans under university autonomy. Moreover, pure loans lead to a lower total surplus.*

Proof. The surplus differential amounts to:

$$S^{PL} - S^{FC} = -\frac{\beta^2\gamma(1-\underline{\theta})}{24} - \frac{3(1-\underline{\theta}^2)}{64\gamma} < 0.$$

Universities enjoy no rents under the uniform fees, so they must be better off under pure loans. However, the total surplus is lower, which implies that students as a whole must be worse off. □

In the present setting, the relaxation of fee competition by means of quality differentiation turns out to be so strong that students as a whole would not profit from substituting optimally administered fees for pure loans with fully autonomous universities. The number of students experiencing a utility loss is higher than the one resulting from removing the central assignment system.

5.2 Graduate Tax

As argued above, the fundamental difference between the pure loan scheme and the graduate tax, consists in a subsidy covering a part of tuition fees, financed by a general tax on all successful students. Thus, the type indifferent between the two quality-tuition fee offers at stage 3 is characterized by $\hat{\theta}^{GT} = (1-\rho)(f_1 - f_2)/(q_1 - q_2)$.

Repeating the above analysis leads to the following stage-2 equilibrium fees:

$$\begin{aligned} f_1^{GT}(q_1, q_2) &= \frac{(2-\underline{\theta})(q_1-q_2)/(1-\rho) + \beta\gamma(1-\rho)(q_1+q_2) - \alpha(2q_1+q_2)}{3} \\ &\quad \frac{+\gamma(2q_1^2+q_2^2) - \beta(1+\underline{\theta}-(1-\rho)\alpha)}{3}, \\ f_2^{GT}(q_1, q_2) &= \frac{(2-\underline{\theta})(q_1-q_2)/(1-\rho) + \beta\gamma(1-\rho)(q_1+q_2) - \alpha(q_1+2q_2)}{3} \\ &\quad \frac{+\gamma(q_1^2+2q_2^2) - \beta(1+\underline{\theta}-(1-\rho)\alpha)}{3}, \end{aligned}$$

with the indifferent type:

$$\hat{\theta}^{GT}(q_1, q_2) = \frac{1-(1-\rho)\alpha + \underline{\theta} + (1-\rho)\gamma(q_1+q_2)}{3}.$$

grants and hence the taxpayers' burden are zero. Nevertheless, a significant number of students would be worse off under pure loans.

This implies the following target functions at stage 1:

$$\begin{aligned}\pi_1 &= B + [2(q_1 - q_2) + (1-\rho)\beta]\frac{(2 - \underline{\theta} + \alpha - \gamma(q_1+q_2))^2}{18(1-\rho)}\\ \pi_2 &= B + [2(q_1 - q_2) - (1-\rho)\beta]\frac{(1 - 2\underline{\theta} - \alpha + \gamma(q_1+q_2))^2}{18(1-\rho)},\end{aligned}$$

with the following equilibrium:

$$\begin{aligned}[q_1^{PL}, q_2^{PL}] &= \left[\frac{5 - \underline{\theta} + 4(\alpha - (1-\rho)^2\beta\gamma)}{8\gamma(1-\rho)}, \frac{5\underline{\theta} - 1 + 4(\alpha - (1-\rho)^2\beta\gamma)}{8\gamma(1-\rho)}\right]\\ \left[f_1^{PL}, f_2^{PL}\right] &= \left[\frac{49 - 16\alpha^2 - 58\underline{\theta} + 25(\underline{\theta})^2}{64\gamma} - \frac{\beta(168 + 120\underline{\theta} - 112\beta\gamma)}{192},\right.\\ &\qquad \left.\frac{25 - 16\alpha^2 - 58\underline{\theta} + 49(\underline{\theta})^2}{64\gamma} - \frac{\beta(168 + 120\underline{\theta} - 112\beta\gamma)}{192}\right],\\ \left[N_1^{PL}, N_2^{PL}\right] &= \left[\frac{1+\underline{\theta}}{2} + \frac{\beta\gamma(1-\rho)^2}{3}, \frac{1+\underline{\theta}}{2} - \frac{\beta\gamma(1-\rho)^2}{3}\right],\end{aligned}$$

and total surplus:

$$\begin{aligned}S^{GT} &= S^{CA} + \frac{(1-\underline{\theta})[1 + 14\underline{\theta} + \underline{\theta}^2 - \rho(14 + 4\underline{\theta} - 14\underline{\theta}^2]}{64\gamma(1-\rho)^2}\\ &\quad - \frac{\beta(1-\underline{\theta})((1-\rho)^3\gamma - 3\rho(1+\underline{\theta}))}{24}.\end{aligned}$$

Proposition 6. *Under a graduate tax, equilibrium qualities, tuition fees and the quality differential are increasing in the subsidy rate. Thus, the graduate tax induces both universities to provide higher teaching qualities than under pure loans. However, the total surplus is decreasing in the subsidy rate. Consequently, the pure loan scheme outperforms the graduate tax with respect to efficiency.*

Proof. The effects on equilibrium qualities and fees follow immediately from differentiating the above expressions. The quality differential $(1-\underline{\theta})/(2\gamma(1-\rho))$ is obviously increasing in ρ. The superiority of the pure loan scheme results from differentiating (22) with respect to ρ and evaluating for $\rho = 0$:

$$\left.\frac{\partial S^{GT}}{\partial \rho}\right|_{\rho=0} = -\frac{(1-\underline{\theta})[18(1+\underline{\theta})^2 - \beta\gamma(28\beta\gamma + 12(1+\underline{\theta}))]}{96\gamma} < 0.$$

As $\frac{\partial S^{GT2}}{\partial \rho^2} < 0$, any increase in the subsidy rate diminishes the total surplus. □.

The economic force driving these results is that students are not confronted with the full cost of their educational decision. This shifts enrolment towards the higher quality institution for given qualities and fees ($\frac{\partial \hat{\theta}^{GT}}{\partial \rho} < 0$). Hence, the higher the subsidy, the higher the quality provided by university 2 in order to offset that loss in demand. Moreover, the subsidy reduces students' enrolment responsiveness with respect to fee increases: ($\frac{\partial \hat{\theta}^{GT2}}{\partial f_i \partial \rho} > 0$). Thus, a given quality differential allows both universities to charge higher fees and strengthens incentives for quality differentiation. , such that university 1 increases its quality by more than university 2.

In total, graduate taxes lead to lower welfare than pure loans. This results from the following effects of a marginal introduction of the subsidy rate. First, the quality of university 2 increases and hence the surplus generated by all students who continue to attend that institution. Second, university 2 attracts more students, which brings about a further efficiency gain by mitigating the enrolment distortion. Third, the increase of q_1 increases or decreases the surplus generated by all students who continue to choose university 1, depending on whether pure loans lead to over- or underprovision. Fourth, however, the subsidy increases the quality enjoyed by those students who attend university 1, but have a success probability below $\hat{\theta}^*$. This creates an inefficiency dominating all the other effects. Thus, while a graduate tax can implement the efficient solution when properly administered, it leads to results inferior to a pure loan scheme under university autonomy.

5.3 Income Contingent Loans

During the last decade, a number of countries, including Australia and the UK, have reformed their system of higher education finance towards income contingent loans (Greenaway and Haynes, 2003). Under these schemes, the state provides an educational loan in the amount desired to each student to be repaid only by the successful ones. The deficit incurred from unsuccessful students is financed by a uniform tax T^{IC} on all households. Thus, in contrast to the other approaches, the general taxpayer remains involved in the financing of higher education.

Faced with the two quality/fee offers at stage 3, students choose universities according to (14). Hence, competition is more intense as the university offering the lower quality-fee differential loses all students. This has obvious implications for tuition fee strategies:

$$f_i(f_j) = \begin{cases} q_i - (q_j - f_j) - \varepsilon & : \quad f_j > q_j - (1+\alpha)q_i + \gamma q_i^2 - \beta(1+\underline{\theta})/2 \\ \{f : f \geq q_j - q_i + f_j\} & : \quad f_j \leq q_j - (1+\alpha)q_i + \gamma q_i^2 - \beta(1+\underline{\theta})/2 \end{cases}$$

Whenever the fee creates some positive per student rent, each university has an incentive to provide an infinitesimal higher quality-fee differential than the competitor. When this difference is non-positive, either university is indifferent between all fees that attract no students at all. Obviously, this gives rise to an infinite number of equilibria, many of which are equivalent in the sense that students enrol at one university only.

We dissolve this indeterminacy by assuming that the university with the worse quality-fee combination sets its fee at a level of at least $\gamma q_i^2 - \alpha q_i - \beta(1+\underline{\theta})/2$. This restriction can be justified by a kind of trembling-hand argument: if some student chose the university with the worse quality-fee combination erroneously, that university would receive a negative per student rent, if the fee were set below that threshold. Then, the reaction functions become:

$$f_i(f_j) = \begin{cases} q_i - (q_j - f_j) - \varepsilon & : \quad f_j > q_j - (1+\alpha)q_i + \gamma q_i^2 - \beta(1+\underline{\theta})/2 \\ \{f : \gamma q_i^2 - \alpha q_i - \beta(1+\underline{\theta})/2\} & : \quad f_j \leq q_j - (1+\alpha)q_i + \gamma q_i^2 - \beta(1+\underline{\theta})/2 \end{cases} \tag{22}$$

leading to the stage 2 equilibrium:

$$f_i = \begin{cases} q_i - q_j + \gamma q_j^2 - \alpha q_j - \beta(1+\underline{\theta})/2 - \varepsilon & : \quad (1+\alpha)(q_i - q_j) \leq \gamma(q_i^2 - q_j^2) \\ \gamma q_i^2 - \alpha q_i - \beta(1+\underline{\theta})/2) & : \quad (1+\alpha)(q_i - q_j) > \gamma(q_i^2 - q_j^2) \end{cases} \tag{23}$$

Income contingent loans allow the university with the higher quality-fee differential to extract almost the whole surplus students enjoy from choosing that university over the competitor. Thus, stage 1 target functions become:

$$\pi_i(q_i, q_j) = \begin{cases} (1+\alpha)q_i - \gamma q_i^2 - (q_j - \gamma q_j^2) + B - \varepsilon & : \quad (1+\alpha)(q_i - q_j) > \gamma(q_i^2 - q_j^2) \\ B & : \quad (1+\alpha)(q_i - q_j) \leq \gamma(q_i^2 - q_j^2) \end{cases}$$

Maximizing the upper part of that expression's right-hand side yields $q_i = (1+\alpha)/(2\gamma)$, equalizing the marginal cost of quality provision with the marginal surplus to be extracted from the students. However, as the fee must be set such as to undercut the competitor slightly, this level allows diversion of funds only if $q_j \leq \bar{q} = \frac{1+\alpha}{2\gamma} - \sqrt{\frac{\varepsilon}{\gamma}}$; where $\pi_i(\frac{1}{2\gamma}, \bar{q}) = 0$. Thus, we get the reaction functions:

$$q_i(q_j) = \begin{cases} \dfrac{1+\alpha}{2\gamma} & : \quad q_j \leq \bar{q} \\ q \in [0, q_j] & : \quad q_j > \bar{q} \end{cases} .$$

If the competitor j chooses a quality less than $\bar{q}$, university i is able to divert some funds towards research by setting the quality $(1+\alpha)/(2\gamma)$ and attracting all students. However, this quality leads to zero diversion, when j chooses at least $\bar{q}$. Then, university i is indifferent between attracting one half of the students and spending all fees on teaching, or attracting no students at all ($q_i < q_j$). As ε is very small, $q^{IC} = (1+$

$\alpha)/(2\gamma)$ is a good approximation of the lower bound of teaching qualities under income contingent loans. This leads to:

Proposition 7. *Under income contingent loans and university autonomy, both universities offer the same teaching quality of at least* $q^{IC} = \dfrac{1+\alpha}{2\gamma}$*, which is inefficiently high:* $q^{IC} > q_1^*$*. No fee revenues are diverted towards research.*

Income contingent loans shift all tuition revenue towards the university offering the higher quality-fee differential. Creating a Bertrand-like situation again, this leads to uniform equilibrium qualities with no diversion. Moreover, the tuition revenue is too high from a social point of view as it contains also the losses arising from failing students. Covered by general taxation, these losses do not affect students' choice between universities and hence add to the rent captured by the university with the higher quality-fee differential.[17]

Comparing income contingent loans with the alternatives when $q^{IC} = \frac{(1+\alpha)}{2\gamma}$, we find:

Proposition 8. *Income contingent loans lead to a lower total surplus than optimally uniform fees. Moreover, the surplus is lower than pure loans unless peer group effects are sufficiently high.*

Proof. Follows from:

$$\begin{aligned} S^{IC} - S^{FC} &= -\frac{1-\underline{\theta}^2}{16\gamma} < 0 \\ S^{IC} - S^{PL} &= -\frac{\beta^2\gamma(1-\underline{\theta})}{24} + \frac{(1-\underline{\theta}^2)}{64\gamma}, \end{aligned}$$

with the latter expression being positive if and only if $\beta > \sqrt{3/8} \cdot (1-\underline{\theta})/\gamma$.□.

Income contingent loans lead to an overinvestment in low ability students, explaining the superiority of uniform fees: $q^{IC} > q_2^*$. This effect is also present in the comparison with pure loans: $q^{IC} > q_2^{PL}$. However, as $q_1^{PL} > q^{IC}$, increasing peer group effects drive more and more students with low ability to the high-quality institution. Therefore, the ranking of alternatives changes when β is sufficiently large.

17 In the light of this inefficiency, it would be interesting to investigate to what extent the performance of income contingent loans could be improved by assigning the losses arising from student failure to the respective university.

6 Conclusion

This paper has investigated how reforms of higher education financing may affect competition among universities and hence the quality of education. It was shown that with administered fees, only the graduate tax is capable to achieve efficiency. Allowing for university autonomy with respect to setting tuition fees leads to inefficiently high teaching qualities or to excessive quality differentiation. Independent of the type of reform, uniform tuition fees, set at the proper level by the government, create a higher surplus in the university sector. Therefore, some government involvement in setting tuition fees seems to be appropriate, provided, of course, that the state faces the correct incentives to implement benevolent policies.

It is interesting to compare the results with those obtained by Garcia-Peñalosa and Wälde (2000). These authors find the pure loan scheme to be dominated by both the graduate tax and income contingent loans with the ranking between the latter ones being ambiguous. In that model, however, total student attendance is endogenous, while the quality of higher education is fixed. In the present approach, the reverse holds: quality is variable, while the total number of students is fixed. However, the ranking of reform alternatives does not reverse in general, but depends on the form of strategic interaction between universities. When tuition fees are set by the government, the present analysis makes a case for the graduate tax. With university autonomy, however, pure loans are always more efficient.

The scarce theoretic literature on higher education competition has concentrated on admission standards as an important feature of university autonomy. This paper, however, emphasizes an equally important point, namely the right to set the level of tuition fees. While an integrated analysis of both aspects of university autonomy would be worthwhile, it is beyond the scope of the paper. Note, however, that both instruments are intertwined as setting a certain fee defines an implicit admission standard by affecting enrolment choices. We conjecture that providing universities with an additional tool to exert market power might aggravate the inefficiencies of the reform proposals.

Students were assumed to be risk-neutral. Relaxing this assumption would not affect the general results obtained, provided that total demand remains unaffected. It would of course be interesting to endogenize the decision of taking up a study or not in order to have a fully-flegded model of higher education reform. However, total demand is typically fixed in models of vertical product differentiation models for reasons of tractability, see also Del Rey (2001). One exception is Wauthy (1996). However, he shows that the structural features of equilibrium depend heavily on the heterogeneity of customers (that is, $\underline{\theta}$ in the present model), even when quality is costless. In the light of the high number of financing alternatives considered here, we leave this as a task for future research.

Appendix

Proof of Proposition 2. As the impossibility of achieving efficiency by uniform fees has been established before, this proof concentrates on differentiated fees $f_1 > f_2$ straightaway. For pure loans and the graduate tax, the quality response functions for either university are given implicitly by the first-order conditions:

$$(\alpha - 2\gamma q_i + \beta \frac{\partial \bar{\theta}_i}{\partial q_i}) N_i - (f_i + \alpha q_i - \gamma q_i^2 + \beta \bar{\theta}_i) \frac{\partial N_i}{\partial q_i} = 0,$$

where both N_i and $\bar{\theta}_i$ depend on the respective financing scheme. Using (5) and (6) yields the following tuition fees inducing universities to provide the efficient quality under both systems:

$$\begin{aligned} f_1^* &= \frac{1-\theta^{*2}}{2\theta^*}(q_1^* - q_2^*) - \alpha q_1^* + \gamma q_1^{*2} - \frac{\beta(1+\theta^*)}{2} \\ f_2^* &= \frac{\theta^{*2} - \underline{\theta}^2}{2\theta^*}(q_1^* - q_2^*) - \alpha q_2^* + \gamma q_2^{*2} - \frac{\beta(\theta^* + \underline{\theta})}{2}. \end{aligned}$$

After inserting the efficient values, these equations imply:

$$\frac{f_1^* - f_2^*}{q_1^* - q_2^*} = \frac{1+\underline{\theta}}{2} + \frac{1+\underline{\theta}^2}{1+\underline{\theta}} - 2\beta\gamma.$$

Under pure loans, this would be compatible with efficiency ($\tilde{\theta}^{PL} = (f_1^* - f_2^*)/(q_1^* - q_2^*) = (1+\underline{\theta})/2$) only if $\beta\gamma = \frac{1+\underline{\theta}^2}{2(1+\underline{\theta})}$ which is ruled out by the assumption on β. However, even if this condition was fulfilled, efficiency would result by chance and not because of the structural features of the pure loan scheme. For the graduate tax, however, efficiency holds when $\tilde{\theta}^{GT} = (1-\rho)(f_1^* - f_2^*)/(q_1^* - q_2^*) = (1+\underline{\theta})/2$. This is accomplished by a subsidy rate

$$\rho^* = \frac{1+\underline{\theta}^2 - 2\beta\gamma(1+\underline{\theta})}{(1+\underline{\theta})^2 + 1 + \underline{\theta}^2 - 2\beta\gamma(1+\underline{\theta})},$$

which is positive, but less than 1. Thus, the superiority of the graduate tax relative to pure loans can be traced back to having an instrument available to influence enrolment decisions without affecting quality choices.

Under income contingent loans, universities' rents are:

$$\pi_i = \begin{cases} B + (f_i + \alpha q_i - \gamma q_i^2 + \beta \bar{\theta}_i)(1-\underline{\theta}) & : \quad q_i > q_j + (f_i - f_j) \\ B + (f_i + \alpha q_i - \gamma q_i^2 + \beta \bar{\theta}_i)(1-\underline{\theta})/2 & : \quad q_i = q_j + (f_i - f_j) \\ B & : \quad q_i < q_j + (f_i - f_j) \end{cases},$$

leading to the quality reaction functions:

$$q_i(q_j) = \begin{cases} \alpha/(2\gamma) & : \quad q_j < \alpha/(2\gamma) - (f_i - f_j) \\ q_j - (f_i - f_j) + \varepsilon & : \quad \alpha/(2\gamma) - (f_i - f_j) \leq q_j < \hat{q}(f_i, \bar{\theta}_i) - (f_i - f_j) \\ q \leq \hat{q}(f_i, \bar{\theta}_i) & : \quad q_j = \hat{q}(f_i, \bar{\theta}_i) - (f_i - f_j) \\ q < q_j - (f_i - f_j) & : \quad q_j > \hat{q}(f_i, \bar{\theta}_i) - (f_i - f_j) \end{cases}, \tag{24}$$

where $\hat{q}(f_i, \bar{\theta}_i)$ is given by (10), with f_i replacing the uniform grant t. Thus, as long the rent is positive $q < \hat{q}(f_i, \bar{\theta}_i)$, either university has an incentive to provide a slightly higher quality than the competitor. Thus, whenever $\hat{q}(f_i, \bar{\theta}_i) - (f_i - f_j) > \hat{q}(f_j, \bar{\theta}_j)$, an asymmetric equilibrium with university i crowding out university j and attracting all students results. As a consequence, the equilibrium must fulfil

$$\hat{q}(f_i, \bar{\theta}_i) - (f_i - f_j) = \hat{q}(f_j, \bar{\theta}_j) \tag{25}$$

in order to have a chance to be efficient. However, this implies that all students are indifferent between both institutions such that $\bar{\theta}_i = \bar{\theta}_j = (1 + \underline{\theta})/2$, ruling out efficient sorting.

But even if students sorted according to ability for whatever reason ($\bar{\theta}_1 = (1 + \theta^*)/2, \bar{\theta}_2 = (\theta^* + \underline{\theta})/2$), income contingent loans miss efficiency but for a single case. Efficient quality setting requires $\hat{q}(f_1^*, (1 + \theta^*)/2) = q_1^*$ and $\hat{q}(f_2^*, (\theta^* + \underline{\theta})/2) = q_2^*$. Solving these conditions for the required fees and subtracting yields:

$$f_1^* - f_2^* = \frac{1 - \underline{\theta}^2}{8} - \frac{\beta(1 - 2\underline{\theta})}{2}.$$

But this expression is equal to $q_1^* - q_2^*$ (see (25)) only if by coincidence $\beta = (1 - \underline{\theta})^2/(4\gamma(2\underline{\theta} - 1))$. Otherwise, the efficient solution can not be implemented as an equilibrium under income contingent loans. □.

Proof of Proposition 4. The comparison of surpluses yields:

$$S^{PL} - S^{CA} = \frac{(1 - \underline{\theta})[1 + 14\underline{\theta} + \underline{\theta}^2]}{64\gamma} - \frac{\beta^2\gamma(1 - \underline{\theta})}{24} > 0.$$

The difference in individual net earnings is:

$$\theta(q_i^{PL} - \alpha/(2\gamma)) - (f_i^{PL} - \alpha^2/(4\gamma)). \tag{26}$$

from which one can derive the ability of the student indifferent between both schemes. Rather than presenting the quite cumbersome expression for this ability level, we present examples establishing the possibility of students being worse off under pure loans. When $\alpha = \beta = 0$, (26) is negative for all students with a success probability below $(49 - 58\underline{\theta} + 16\underline{\theta}^2)/(40 - 8\underline{\theta})$. This level is always lower than one, but higher than $\underline{\theta}$ if and only if $\underline{\theta} < 7/12$. Thus, all students are better off under pure loans when student heterogeneity is sufficiently low. When $\alpha = 1, \beta = 0$, the threshold ability to be better off under pure loans becomes $(49 - 42\underline{\theta} + 16\underline{\theta}^2)/(40 - 8\underline{\theta}) \gtrless 1 \iff \underline{\theta} \lesseqgtr 0.3099$. When $\alpha = 1, \beta = 1/(4\gamma)$, the critical ability becomes $(28 - 39\underline{\theta} + 12\underline{\theta}^2)/24 - 6\underline{\theta}) < 1$. This level is lower than $\underline{\theta}$, if and only if $\underline{\theta} < 0.5224$. $\square$.

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