The expansion in the higher education sector: A tale of two regions[*†]

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Abstract

The higher education sector has experienced an international boom in the last 30 years: an important number of universities have been created while the proportion of adults with higher education has doubled within this period. However, universities not only provide students with more human capital but also undertake research activities. In this paper we analyze whether or not the expansion in the number of universities is optimal from an aggregate excellence point of view, taking into account that universities act strategically when competing for both teaching and research funds. In particular we focus on the role of the type of university (research versus non research oriented) in this comparison.

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1 Introduction

The importance of universities and higher education providers to the national economy is becoming increasingly well recognized across Europe.[1] Higher education now provides the skill and the knowledge transfer that enables regions to grow and to attract new investment. At the same time, globalization and increased international competition has come with increasing scrutiny of the differences in the performance of countries' universities and therefore highlighting the importance of making higher education institutions attractive to the world. This issue is of special interest due to the recent evidence regarding the poor performance of the European Higher Education System and its comparison with the US one (which seems to be better placed to compete with the new academic producers in Asia).[2] and the ongoing debate on the role that the research and teaching quality provided by universities may play in the transformation of knowledge into competitiveness and innovation.

The evidence regarding the link between the poor performance of the European universities and the lower growth rates experienced in Europe has triggered different higher education reform proposals across Europe. In particular, universities, research centers and firms are being encouraged to form associations in order to receive public funds.[3] All these programs share the same objectives: reinforce national universities making them more competitive, visible and reputable in an international context and attract better professors, researchers and students.

An analysis of US universities may lead us to conclude that more autonomous universities that need to compete more for resources are more productive.[4] In the European context this would be an argument against the aggregation of universities

[1]There is a large literature on education and growth (see, among others Acemoglu (2009)). However note that this literature tends to use aggregate measures of education (e.g. average years attained) and does not differentiate education investments by type or expenditure, and certainly does not differentiate them by governance of schools.

[2]In 2003, the Institute of Higher Education of the Shanghai Jao University released the first "Shanghai ranking" where most European universities ranked low -or did not rank at all. See also Aghion et al. (2009) for details on the comparison between European and US universities according to international rankings.

[3]For example, in 2006 Germany launched the "Initiative for Excellence" (2006-2012) program. At the same time, France launched the program "Pôles de Recherche et Enseignement Supérieur" (PRES 2006). Lately, Spain has just developed the initiative "Campus de Excelencia Internacional" in 2009.

[4]Nevertheless, observe that US higher education institutions come in a wide variety of shapes and sizes.

and for the expansion of higher education market (that is, an increasing number of universities). The success of the American Higher Education System is a result of its own organization and funding system. Therefore it is important to take into account the relationship between the prevailing funding policies for higher education institutions in Europe and their institutional behaviour since this relationship is going to determine their performance in terms of excellence and thus it is crucial to check whether the reforms that are being implemented are in the right direction.

This paper contributes to this debate by addressing two main questions. First, to what extent the aggregation of higher education institutions, implemented by these reforms, is a valid instrument to alter the reputation of existing institutions? In other words, is it always valid the argument that increasing competition for resources and faculty candidates induces higher excellence? Second, does the university type (research or non-research focused) play any role in the determination of aggregate excellence when there is competition for resources and faculty candidates?

We construct a simple model where universities act as non-profit institutions with the goal of maximizing prestige or excellence subject to a budget constraint in a framework where universities act strategically when competing for both teaching and research funds. They do so by choosing the quality of their faculty members, which in turn determine their income and prestige. Hence, in our model universities compete for both faculty candidates and resources. The university type (research versus non-research) determines the way universities compete for candidates. We analyze university performance within two areas: in one of them there is just one university while in the other there are two universities competing for candidates and/or resources. Finally, we also assume that acquiring quality is costly and interpret different costs as different reputation levels.

Our paper draws upon the literature on university governance. De Fraja and Iossa (2002) point out that increased student mobility favors the emergence of elite institutions and explore how strategic admission setting can lead to quality stratification of higher education institutions. Del Rey (2001) investigates the strategic choice of universities between teaching and research activities, focussing on how the financial allocation between both can be controlled by a proper choice of the government's parameters. However, in her model research is treated as a residual item and no attention is paid to its quality. Beath et al. (2005) develop a model that incorporates research quality directly into a university's budget constraint and provide a rather general setting that allows universities to actively choose the quality of their teaching and research when facing different funding systems. Nevertheless, they do not consider inter-university competition. Recently, Gautier and Wauthy (2007) analyze the possible implications of incentive schemes as a tool to promote efficiency in the management of universities. They analyze a multitasking agency problem where there is competition for resources between departments within the same university and the objectives of academics and authorities are different. Finally, Aghion et al. (2009) investigate how university governance affects research output and show that university autonomy and competition are positively correlated with university output, both among European and US public universities.

This paper studies the choice of education providers facing the decision to promote or not the creation of a new university. This decision can be interpreted in two different way: on the one hand, the new university can be the aggregation of two established universities in an area (Region A in the paper). On the other hand, education providers consider the possibility to launch a new university in an area where there is already one university that will compete with the new one for resources and/or faculty candidates. That is, we analyze the impact of the creation of new universities on aggregate excellence. We focus on the role of the type of university (research versus non research oriented).

Our main finding is that, regardless of the university type (research or non-research oriented) university aggregation is not necessarily good or, reversibly, university duplication is not necessarily bad. We also show that the relationship between cost differentials of universities competing within the same area, the amount of research funds and universities´ strategic quality choice plays a key role when comparing aggregate excellence between areas.

The paper is organized as follows. Section 2 introduces the model. Section 3 analyzes the region where there is only one university operating. Section 4 analyzes the region where there are two universities competing. Section 5 compares both regions according to aggregate excellence. Finally, Section 6 concludes. Cumbersome proofs are relegated to the Appendix.

2 The Model

In this section we describe the behavior of the agents comprised in the higher education market.

2.1 The universities

Universities are assumed to be organizations whose aim is to maximize their prestige or excellence (see Winston (1995) and Clotfelter (1999) for a detailed analysis of the universities' goal). To achieve this objective universities hire the most able faculty members, admit the brightest students and pursue the highest-quality academic and cultural environment. To sharpen the analysis we consider that the excellence of university i, E_i, depends positively on two factors: first, the quality-weighted number of faculty members, $n_i x_i$, where n_i denotes the number of candidates hired and $x_i \in [0,1]$ denotes the admission standard or minimum level of ability that university i requires to faculty candidates. And second, the expenditure on maintaining and improving the quality of campus facilities, F_i.[5] To further simplify, we propose the following objective function:

$$E_i = n_i x_i + \delta F_i, \tag{1}$$

where $\delta > 0$ measures the weight of the quality of campus facilities on excellence.[6] Alternatively, this objective function can be understood as if each university aims at maximizing "income or rents" from research and teaching. The inclusion of both teaching and research quality in universities' objectives can be easily justified by the desire to obtain reputation for both activities.

While all universities undertake teaching activities, some of them may perform research as well. Financing is provided by some funding agency. In particular, the total amount of funds that each university i receives to finance its teaching activities is tn_i, where t can be interpreted as the students/lecturer ratio, thus $t > 1$. Therefore, teaching funds are increasing in the number of candidates hired (or reversibly, increasing in the total number of students for some fixed number of faculty members).

Universities performing research activities can obtain extra funds through research grants to finance them. We denote by G the total grant that will be allocated among

[5] The quality of campus facilities, F_i, may include to offer small class size, enhancing extracurricular activities, tuition discounts and other financial aid considerations to students. It may also include research facilities: labs, research assistants, sabbatical, etc.

[6] De Fraja and Iossa (2002) proposed a very similar university objective function. However, they put emphasis on the admission standard mechanism to select students. While it is a crucial issue, our framework abstracts from analysing students' behavior since it is not the main focus of this paper. Instead, we are implicitly assuming that by hiring the best lecturers and providing the best campus facilities, universities can attract more students and this fact allows them to select the best students (Winston (1995) and Epple, Romano and Sieg (2007) use a similar argument in their models).

those universities undertaking research activities. Each university i engaged in research activities gets a proportion $p_i(x_i)$ of G.

Finally, we assume that setting any admission standard is costly. In particular, the total cost of setting an admission standard x_i is $\alpha_i x_i$, where $\alpha_i \in (0,1)$ is the cost of acquiring one extra unit of quality. In addition, we also assume that different universities may have different reputations for the teaching and research quality they provide. This means that seeking for faculty candidates and research funds is less costly for a university with a higher reputation level.[7]

To sum up, the total amount of resources R_i, that each university i can get is given by:

$$R_i(x_i, \gamma_i) = tn_i(x_i) + \gamma_i p_i(x_i)G - \alpha_i x_i, \tag{2}$$

where the parameter $\gamma_i \in \{0,1\}$ is a dummy variable summarizing university i activity focus. If university i just performs teaching activities then $\gamma_i = 0$. In this case we will refer to university i as a non-research oriented university. If, in addition to teaching it also performs research activities then $\gamma_i = 1$. In this case we will refer to university i as a research oriented university.

Finally, each university spends those resources on paying salaries S_i, and maintaining facilities F_i. Thus, university i budget constraint is:

$$F_i + S_i = R_i. \tag{3}$$

In line with the empirical evidence we assume that the salary scheme is equal to $t + \gamma_i x_i$. The key idea is that the willingness to accept a position is positively related to the quality of the university.[8] That is, each candidate receives a minimum wage equal to the fixed amount that the university receives from the funding agency. Thus,

[7] As Graves et al. (1982) point out, universities' reputation serves several related functions. Faculty candidates can use such reputation as a proxy for the quality of the research/teaching environment at particular universities. For students, such reputation is suggestive of the faculty skills and knowledge. Finally, reputation serves as a signal of trustworthiness to the funding agency.

[8] Graves et al. (1982) find that departments that have a high number of published works per faculty member are departments that pay higher salaries. In addition, the best research teams are more likely to be given research contracts. According to the 2008-09 Report on the Economic Status of the Profession, released by the American Association of University Professors, the average salary in doctoral granting institutions (research universities) is higher than in institutionss offering undergraduate/baccalaureate programs (non-research oriented universities). In addition, this assumption on salary scheme is commoly accepted in related literature. See, for example, Del Rey and Wauthy (2007).

the fixed component of the university's net profit per candidate hired is equal to cero. Below we comment on the consequences of this assumption and how the results of the paper might change if we relax it. The total salary bill is $S_i = (t + \gamma_i x_i)n_i$.

We focus on the impact of increased competition on aggregate excellence achieved by the whole university system. Thus, we consider that the type of the university is given and universities only set their admission standard x_i by solving the following maximization problem:[9]

$$\begin{aligned} \underset{\{x_i\}}{Max} \quad & E_i(x_i, \gamma_i) = x_i n_i(x_i) + \delta F_i \\ s.t. \quad & F_i + S_i \;=\; R_i. \end{aligned} \tag{UP}$$

Using Equation (2), university i's maximization problem becomes:

$$\underset{\{x_i\}}{Max} \quad E_i(x_i, \gamma_i) = x_i n_i(x_i) + \delta\left(\gamma_i(p_i(x_i)G - x_i n_i) - \alpha_i x_i\right) \tag{4}$$

Thus, from (4) it can be checked that the precise university type (research vs non-research oriented) determines the way to achieve excellence. In particular, a non-research oriented university ($\gamma_i = 0$) aims at maximizing the difference between the quality-weighted number of faculty members and the cost incurred to acquire quality:

$$\underset{\{x_i\}}{Max}\ E_i(x_i, 0) = x_i n_i(x_i) - \delta\alpha_i x_i.$$

Similarly, for a research oriented university ($\gamma_i = 1$) the problem stated in (4) translates into maximizing a convex combination between its net research revenues and its quality weighted number of candidates:

$$\underset{\{x_i\}}{Max}\ E_i(x_i, 1) = (1-\delta)x_i n_i(x_i) + \delta(p_i(x_i)G - \alpha_i x_i).$$

In what follows, α_i is assumed to be low enough such that the maximum excellence level will not be achieved for $x_i^* = 0$. Otherwise, corner solutions would arise with universities providing no quality at all. In order to rule out this possibility we establish the following assumption.

Assumption 1(A.1): $\alpha_i < \min\{1/N\delta, G\}$.

Where $N = 1, 2$ denotes the number of universities operating in the higher education market. Assumption A.1. ensures that universities do not find optimal to hire

[9] Hidalgo and Valera (2009) analyze universities decision on both: the (minimum) admission standard and their type (research vs. non-research oriented).

the whole population of faculty candidates (even those with the least ability levels). This might happen if the cost of acquiring one extra unit of quality, α_i, is very high.

2.2 The faculty candidates

There is a continuum of faculty candidates that differ according to their research and teaching ability. For convenience we assume that candidates are uniformly distributed in the interval [0,1].[10] Only those candidates with ability above x_i, the admission standard set by university i, are offered a position at university i where they engage in either teaching or research (depending on the type of university that hires them). Note that we do not exclude the possibility that universities become so selective that they do not hire any new candidate ($x_i = 1$). That is, they can decide whether or not to expand along the next period.

We also assume here that candidates' utility is increasing with wages and does not depend on the type of university that hires them (research or non-research oriented). Since the paper is not concerned with the research and teaching performances of single academics, but with those of a whole institution this assumption allows us to focus on universities' optimal choices rather than on that of faculty candidates.

In the following sections we analyze two higher education market structures: the single university monopoly market structure, and a duopoly market structure.

3 Region A: one university

In this section we consider that there is just one university labelled A operating in the higher education market. This university can also be interpreted as the result of a process of aggregation of two (or more) universities with joint proposals.[11]

Thus, given an admission standard x_A, the number of candidates hired by this university is equal to $n_A(x_A) = 1 - x_A$ regardless of its type (research or non-research oriented).

Next we analyze the university's optimal decision. We denote by E_A^γ the equilibrium aggregate excellence achieved in Region A when its university is specialized in the activity type captured by parameter γ, that is, $E_A^\gamma = E_A(x_A, \gamma)$. We begin our

[10] To simplify matters, we consider a perfect correlation between the ability to teach and the ability to perform research (see Wood and DeLorme (1976)).

[11] See the recent cases of Germany, France and Spain.

analysis with university A being non-research, that is, $\gamma_A = 0$. It is easy to check that under (A.1) the university A's excellence function, E_A^0, is increasing and concave on x_A. In particular, we obtain that the unique optimal admission standard is given by $x_A^* = \frac{1-\delta\alpha_A}{2}$. Hence, the resulting equilibrium excellence level is equal to:

$$E_A^0 = \left(\frac{1-\delta\alpha_A}{2}\right)^2. \tag{5}$$

To maximize prestige, the non-research university decides to expand in size by choosing an admission standard lower than 1. Note that its optimal admission standard is decreasing in the cost of acquiring quality α_A and the weight of facilities on excellence. That is, as the weight of facilities on excellence increases then the number of candidates increases but its quality diminishes. Now we turn to the case where university A is research oriented, i.e., $\gamma_A = 1$. If this is the case, it can get a proportion of the total research grant G equal to its admission standard. That is, we assume that $p_A(x_A) = x_A$. It is easy to check that under (A.1) the university A's excellence function, E_A^1, is increasing and concave on x_A. Hence, university A optimal admission standard is $x_A^* = \frac{(1-\delta)+\delta(G-\alpha_A)}{2(1-\delta)}$. Note that its optimal admission standard is decreasing in the cost of acquiring quality α_A and increasing in the weight of facilities on excellence. That is, the higher the weight of facilities on excellence the lower the number of candidates but the higher its quality. In addition observe that the optimal admission standard for a non-research university coincides with that of a research university whenever the weight of facilities on excellence δ is equal to zero. As the weight of facilities on excellence increases the difference between the optimal admission standard for the non-research and the research university increases.

The excellence achieved by the research university A at the optimum is then:[12]

$$E_A^1 = \frac{((1-\delta)+\delta(G-\alpha_A))^2}{4(1-\delta)}. \tag{6}$$

Next we introduce competition in the higher education market and compare the results with the ones above.

4 Region B: two universities

Consider now a different region with two universities operating in there labeled 1 and 2. We assume that these universities differ according to their cost of acquiring one

[12]Note also from (A.1) that if $\delta = 1$ then $x_A^* = 1$ and $E_A^1 = G - \alpha_A$.

extra unit of quality or established reputation, α. In particular, we will assume that $\alpha_1 < \alpha_2$ that is, university 1 is more reputable than university 2. This means that attracting faculty candidates and research funds are both less costly for university 1 than for university 2.[13] Nevertheless, below we comment on the results for $\alpha_1 = \alpha_2$.

We analyze a game where the activity focus of each university, γ_i, is established. Both universities choose their admission standard (x_1, x_2) simultaneously taking the admission standard of the competitor as given.[14] Hence, the university i (for $i = 1, 2$) maximization problem is:

$$\begin{aligned} \underset{\{x_i\}}{Max} \quad & E_i(x_i, x_j) = x_i n_i(x_i, x_j) + \delta F_i \\ s.t. \quad & F_i + S_i = R_i(x_i, x_j, \gamma_i). \end{aligned} \tag{7}$$

Now we proceed to analyze the optimal admission decision of both universities. Consider first the case where there is specialization in Region B and thus one university is non-research oriented whereas the other is research oriented. In particular, $\gamma_1 = 1$ and $\gamma_2 = 0$. As we will see below the optimal admission standard set by the research oriented university in Region B is similar to the admission standard chosen by the university in Region A, whenever it is research oriented.

Observe here that in the context of specialization there is no competition for resources between the two universities operating in Region B. Instead they just compete for faculty candidates, facing a trade-off between its quantity (the number of faculty candidates) and its quality (the admission standard chosen).

The salaries offered by university 1 and 2 are respectively $t + x_1$ and t. As long as $x_1 = 0$ any candidate, if admitted, randomizes between working at any of the two universities and both share equally candidates with ability $x > x_2$, whereas candidates with ability $x \leq x_2$ just join university 1. Similarly, if university 1 sets $x_1 > 0$ any candidate, if admitted, works at university 1 since there she gets the highest salary. Therefore, university 2 does not hire any candidate unless it sets $x_2 < x_1$. Thus, the number of candidates hired by university 2 is:

[13] This initial reputation differential is best understood as resulting from established quality inherited from the past.

[14] We think this approach is more appropriate than considering sequential decisions since in the higher education market the entry of additional programs or universities is regulated, implying that institutions cannot simple add more programs to their portfolio as long as that is profitable. In addition our focus is on universities' behaviour while operating in the higher education market rather than on universities' decision on whether or not entering into the higher education market.

$$n_2(x_1,x_2) = \begin{cases} \frac{1-x_2}{2} & if \quad x_2 \geq x_1 = 0 \\ x_1 - x_2 & if \quad 0 \leq x_2 < x_1 \\ 0 & if \quad x_2 \geq x_1 > 0, \end{cases} \tag{8}$$

whereas the number of candidates hired by university 1 is:

$$n_1(x_1,x_2) = \begin{cases} \frac{1+x_2}{2} & if \quad x_1 = 0 \\ 1 - x_1 & if \quad x_1 > 0. \end{cases} \tag{9}$$

Finally, if there just one university undertaking research activities ($\gamma_i = 1, \gamma_j = 0$) then $p_i(x_i) = x_i, \forall x_i$ for $i \neq j$. That is, G will not be fully allocated unless the research-oriented university sets the highest admission standard.

Each university solves the problem described in (7) where $\gamma_1 = 1, \gamma_2 = 0$ and $n_2(x_1,x_2)$ and $n_1(x_1,x_2)$ are given by equations (8) and (9), respectively. The equilibrium in which $\gamma_1 = 0$ and $\gamma_2 = 1$ can be obtained by simply permuting subscripts 1 and 2. The following proposition describes it.

Proposition 1 *Let $\gamma_1 = 1$ and $\gamma_2 = 0$ and $\alpha_1 \leq \alpha_2$. Then, under (A.1) there is a unique equilibrium where $x_2^* < x_1^*$.*

Proof. See the Appendix. ■

Thus, in this case the unique equilibrium is such that the non-research oriented university (university 2) sets a lower admission standard than university 1 and manages to hire some candidates.

Note from the proposition above that, if university 2 (here the one with the highest cost of acquiring quality) were the research-oriented one, we would have that the unique equilibrium would be such that $x_1^* < x_2^*$, where $x_1^* = \dfrac{1-\delta\alpha_1}{2}$. It is easy to see that since $\alpha_1 < \alpha_2$ the difference between the admission standards set by both universities in the case where university 2 is the teaching-oriented is higher than in the case where university 2 is the research-oriented one. In other words, the university with the highest cost of acquiring quality (university 2) hires more candidates than the university with the lowest cost of acquiring quality (university 1) whenever it chooses to become teaching-oriented in the case where one university chooses to do research and the other teaching. Finally it can also be checked that both universities face the same cost of acquiring quality, i.e., $\alpha_1 = \alpha_2 = \alpha$, then from Proposition 1 we have that $x_2^* < x_1^*$.

Now we proceed to analyze the case where there is no specialization in Region B. That is, either none university is research oriented or both universities are research oriented. To further simplify we assume that $\delta = 1$. As commented above this leads to extreme differences between optimal admission standard chosen by the research and the non-research oriented university. In that sense we should interpret the following results as magnified tendencies.

As we will see below the equilibrium where the most reputable university sets the highest admission standard, i.e., $x_1^* \geq x_2^*$ always exists regardless of both universities activity focus. Such an equilibrium may not be unique. In fact, the equilibrium where the most reputable university sets the lowest admission standard may arise for some parameter configuration.

4.1 Non-research oriented universities

Here we assume that both universities are non-research oriented. Thus, universities do not compete for resources but for faculty candidates, where again they face a quantity-quality trade-off.

Given the salary scheme, a faculty candidate when being admitted to both universities, randomizes between working at any of them. Thus, the partition of candidates between both universities is as follows:

$$n_i(x_i, x_j) = \begin{cases} \dfrac{1 - x_j}{2} + (x_j - x_i) & if \quad x_i < x_j \\ \dfrac{1 - x_i}{2} & if \quad x_i \geq x_j. \end{cases} \tag{10}$$

That is, if both universities set the same admission standard, each university hires half of the total number of admitted lecturers. If they set a different admission standard, $x_i > x_j$, both universities share equally those lecturers with ability higher than x_i, whereas those lecturers with ability $x \in [x_j, x_i]$ just join university j. Each university solves the problem described in (7) with $\gamma_i = 0$ for $i = 1, 2$ and $n_i(x_i, x_j)$ given by Equation (10).

In the following proposition we show that, under Assumption 1, there is no equilibrium in which both universities set the same admission standard. In addition we show that the equilibrium where the most reputable university sets the highest admission standard always exists, i.e., $x_1^* > x_2^* \geq 0$. That is, as the most reputable university is the most efficient in acquiring quality, it is optimal for this university to set the highest admission standard. Nevertheless, we also find that the equilibrium where the least reputable university sets the higher admission standard may emerge when the cost differential between universities is sufficiently small. In particular, $\widehat{\alpha}_1(\alpha_2)$ defined a threshold level for the cost of acquiring quality of university 1 that determines in the α_2, α_1 space whether the initial differential cost between both universities is high (the region below $\widehat{\alpha}_1(\alpha_2)$) or low (the region above $\widehat{\alpha}_1(\alpha_2)$).

Proposition 2 *Let $\gamma_i = 0$ for $i = 1, 2$ and $\alpha_1 \leq \alpha_2$. Under (A.1) then:*

(i) There is no equilibrium such that $x_i = x_j = x$.

(ii) If $\alpha_1 \leq \widehat{\alpha}_1(\alpha_2)$ there is a unique equilibrium where $x_1^* > x_2^* \geq 0$.

(iii) If $\alpha_1 \geq \widehat{\alpha}_1(\alpha_2)$ there is multiplicity of equilibria where either $x_1^* > x_2^* \geq 0$ or $x_2^* > x_1^* \geq 0$.

Proof. See Appendix. ■

Several comments can be made here. First observe that given any admission standard set by university i, university j has always incentives to deviate and set a higher or a lower admission standard than university i to hire the most able candidates or the highest number of candidates respectively. The idea behind this result is the that since both universities are non-research oriented their excellence depends on the quality and the size of the institution.

Second, if the difference in the cost of acquiring quality between both universities is very high (the region below $\widehat{\alpha}_1(\alpha_2)$), the most reputable university (here university 1) can induce university 2 to set a lower admission standard. As a result, university 1 manages to hire the best candidates and achieves a higher excellence level than university 2. However, when the costs of acquiring quality are similar or equal (the region above $\widehat{\alpha}_1(\alpha_2)$) both types of equilibria may arise. This is so because no university can induce the other to set a lower admission standard and university 2 tries to overcome the initial cost differential by hiring the most able candidates.

Here Figure 1 (Region B: The non-research admission equilibria)

Figure 1 illustrates the previous result in the (α_2, α_1) space. It depicts the set of equilibria corresponding to the case where both universities operating in Region B are running non-research oriented universities. If the cost differential is low enough, that is if $\alpha_1 \geq \widehat{\alpha}_1(\alpha_2)$, then multiplicity of equilibria arises where either $x_1^* > x_2^*$ or $x_1^* < x_2^*$. If the cost differential is not that low then there is a unique equilibria where $x_1^* > x_2^*$.

The following remark summarizes the equilibrium result when both universities face the same cost of acquiring quality.

Remark 3 *Let $\gamma_i = 0$ for $i = 1, 2$. If $\alpha_1 = \alpha_2 = \alpha$ then there is multiplicity of equilibria where either $x_1^* > x_2^*$ or $x_1^* < x_2^*$.*

Proof. It is immediate from Proposition 2. ■

Thus, if both universities have the same cost of acquiring quality, $\alpha_1 = \alpha_2 = \alpha$ then both equilibria exist and either $x_1^* = \frac{1}{2}(1 - 2\alpha)$ and $x_2^* = \frac{3}{8}(1 - 2\alpha)$ or the other way around.

From Proposition 3 we have that in the equilibrium where the most reputable university sets the highest admission standard, $x_1^* = \frac{1}{2}(1 - 2\alpha_1)$ and $x_2^* = \frac{1}{8}(3 - 2\alpha_1 - 4\alpha_2)$. From equations (7) and (10) we have that the resulting excellence values for university 1 and 2 are, respectively:

$$
\begin{aligned}
E_1(x_1^*, 0) &= \frac{1}{2}\left(\frac{1 - 2\alpha_1}{2}\right)^2 . \\
E_2(x_2^*, 0) &= \left(\frac{2\alpha_1 + 4\alpha_2 - 3}{8}\right)^2 ,
\end{aligned}
\tag{11}
$$

where it can be checked that $E_1(x_1^*, 0) > E_2(x_2^*, 0)$ for any $\alpha_1 < \alpha_2$. That is, if both universities operating in the higher education market are non-research oriented, then in equilibrium, the university with the lowest cost of acquiring quality achieves more aggregate excellence than the other university. In particular, the university that exhibits the highest cost of acquiring quality (and therefore a more difficult acces to funds) may not overcome the initial cost disadvantage by setting a larger university than the other university (since $x_1^* > x_2^*$ then from (10) $n_2 > n_1$). As long as $x_1^* > x_2^* \geq 0$ this result is driven by the fact that university 1 hires the best and sets a limiting admission standard such that there will not be enough candidates with an ability level $x \in [x_2, x_1]$ so that university 2 can overcome its cost disadvantage by means of increasing its size.

Finally, if we look at the aggregate level of excellence in both cases we find that aggregate excellence achieved in the equilibrium where $x_1^* > x_2^*$ (the "good" scenario) is higher than the one achieved in the equalibrium where $x_2^* > x_1^*$ (the "bad" scenario). We restrict our attention to the first case. The reason for that is that our analysis reveals that even when this “good” scenario arises competition (understood here as more participants in the higher education market) can generate worse results in terms of aggregate excellence than a monopoly. If this is the case, the "bad" scenario may only reinforce our main results and the need for public intervention. In fact, our results seem to support some recent policy initiatives that try to promote aggregations among established universities.

4.2 Research oriented universities

Now we assume that both universities are research oriented and thus $\gamma_i = 1$ for $i = 1, 2$. Before solving for the optimal admission decision, we need to fully specify the function $p_i(x_i, x_j)$ which determines the proportion of total research grant that university i (for $i = 1, 2$) can get depending on the relative admission standard set by each university. In particular, if both universities are undertaking research activities, then:

$$p_i(x_i, x_j) = \begin{cases} \dfrac{x_i}{x_i + x_j} & if \quad x_i + x_j > 0 \\ 0 & if \quad x_i + x_j = 0. \end{cases} \tag{12}$$

This reward structure can be interpreted as a particular tournament where there is a rank-order payment scheme.[15] Thus, we assume that universities always receive a proportion of the award G as long as they set a positive admission standard. Note that, provided that both universities are research-oriented the funding agency always fully allocates G except for the case when both research universities choose the lowest admission standard. If this is the case, no award is provided.

Given the salary scheme a candidate, when being admitted to both universities, chooses to work at the one with the highest admission standard since there she gets the highest salary. Each university solves the maximization problem described in (7) where $\gamma_i = 1$ for $i = 1, 2$ and $\delta = 1$.

The following proposition characterizes the optimal admission standard set by both universities in equilibrium. It shows that the equilibrium admission standard set by each university is increasing in the amount of the research grant, G. In particular, if $G < \underline{G}$, where $\underline{G}$ stands for $\underline{G}(\alpha_1, \alpha_2) = \frac{(\alpha_1+\alpha_2)^2}{\alpha_2}$ then the admission standard set

[15] Tournaments are extensively used as allocation mechanisms, see Lazear and Rosen (1981). However, in contrast with the usual tournament set up, in our model there is no uncertainty with respect to the admission standard chosen by the university. Gautier and Wauthy (2007) find that the optimal allocation of resources among departments should be based on the relative performance of their research projects.

by both universities is below one. However if $G > \overline{G}$, where $\overline{G}$ stands for $\overline{G}(\alpha_2) = 4\alpha_2$ then the admission standard set by both universities is equal to one. Finally, Proposition 5 shows that there is no symmetric equilibrium and that the most reputable university always sets the highest admission standard.

Proposition 4 *Let $\gamma_i = 1$ for $i = 1, 2$ and $\alpha_1 \leq \alpha_2$. The optimal admission standard x_i^* depends on the total research grant:*

(i) If $G > \overline{G}$ then $x_2^* = x_1^* = 1$.

(ii) If $G \in (\underline{G}, \overline{G})$ then $x_2^* < x_1^* = 1$.

(iii) If $G < \underline{G}$ then $x_2^* < x_1^* < 1$.

Proof. See the Appendix. ■

Proposition 3 shows first that, provided that both universities differ in the cost of acquiring quality and regardless of the amount of the research grant, there is no symmetric equilibrium in which both universities admit, at least, some candidates but not all of them, i.e., there is no equilibrium where $x_1^* = x_2^* = x$, and $x \in (0, 1)$.

The following remark summarizes the equilibrium result when both universities face the same cost of acquiring quality.

Remark 5 *Let $\gamma_i = 1$ for $i = 1, 2$. If $\alpha_1 = \alpha_2 = \alpha$ then $x_1^* = x_2^* = x$ where $x = (<)1$ for $G \geq (<)\overline{G}(\alpha)$*

Proof. It is immediate from Proposition 4. ■

That is, if both universities face the same cost of acquiring quality, α, then a symmetric equilibrium arises, i.e. $x_1^* = x_2^* = x$ where $x = (<)1$ for $G \geq (<)4\alpha$. This contrast the case where the two universities operating in the higher education market are non-research oriented (see Remark 3 above) where no symmetric equilibrium arises regardless the cost differential between both universities.

The reason for that is the following. When there are two non-research oriented universities they compete in quality and size. Given the salary scheme and the resulting market partition of faculty candidates, the fact that there are non differences in the cost of acquiring one extra unit of quality allows both universities to compete in either quality of size as none of them can take advantage of any of the two variables. Thus, the one that sets the lower admission standard takes advantage of size while the other takes advantage of quality to reinforce its prestige. On the other hand, when both universities are research oriented they compite for research funds. Observe that due to the reward scheme designed by the funding agency the only device they have to get the maximum amount of the research grant -and hence maximize excellence- is its quality or admission standard. That is, a research university can only take advantage by setting a higher admission standard than its competitor.

The second interesting result from Proposition 4 is that the most reputable university always sets the highest admission standard. In addition and non surprisingly, the admission standard set by each university in equilibrium increases with the amount of the research grant G. We consider in turn each possible equilibrium configuration, where we have to distinguish three alternative scenarios depending on the amount of funds devoted to finance research. First, if $G > \overline{G}$ we get that the excellence values for both universities is:

$$\begin{aligned} E_1(x_1^*, 1) &= \frac{G}{2} - \alpha_1. \\ E_2(x_2^*, 1) &= \frac{G}{2} - \alpha_2, \end{aligned} \tag{13}$$

The huge amount devoted to finance research induces an increase in competition among universities in such a way that admission standards are increased to the utmost. As a consequence, the research grant G is split equally between the two universities no matter the cost of acquiring quality. It is straight forward to see that university 1 achieves a higher excellence level since it benefits from its advantage in reputation. Nevertheless, an inefficiency in allocating research funds may emerge as long as the differences in cost are sufficiently large. We will discuss this issue in the next section. If the research grant is not that high, in particular, $G \in (\underline{G}, \overline{G})$ then:

$$\begin{aligned} E_1(x_1^*, 1) &= \sqrt{\alpha_2 G} - \alpha_1. \\ E_2(x_2^*, 1) &= G + \alpha_2 - 2\sqrt{\alpha_2 G}, \end{aligned} \tag{14}$$

Recall from Proposition 3 that in this case, university 1 sets a higher admission standard than university 2. However, the excellence value of university 1 remains higher than that of university 2. And finally if the research grant is low enough, i.e. $G < \underline{G}$:

$$\begin{aligned} E_1(x_1^*, 1) &= \left(\frac{\alpha_2}{\alpha_1 + \alpha_2}\right)^2 G. \\ E_2(x_2^*, 1) &= \left(\frac{\alpha_1}{\alpha_1 + \alpha_2}\right)^2 G. \end{aligned} \tag{15}$$

That is, if we consider the case where research funds are scarce, we obtain that, as before, university 2 needs to set a lower admission standard that university 1. However still, the excellence value of university 1 remains higher than that of university 2.

To conclude, in the scenario where both univerisities are research oriented, and as a result of the competition between both, then the excellence level achieved in equilibrium is higher for university 1 (the most reputable) than for university 2 regardless of the amount devoted to finance research. That is, $E_1(x_1^*, 1) > E_2(x_2^*, 1)$ for any G.

In the following section we compare aggregate excellence between Region A and B without specialization, that is, either none university is research oriented or both universities are research oriented.

5 Region A vs. Region B

In this section we will compare aggregate excellence in Region A and Region B whenever there is no specialization between the two universities competing in Region B regarding their activity type. That is, $\gamma_1 = \gamma_2 = \gamma$.

Recall that the university operating in Region A can be interpreted as the result of a process of aggregation of two (or more) universities with joint proposals.

We denote by E_B^γ the equilibrium aggregate excellence achieved in Region B when both universities are specialized in the activity type captured by parameter γ:

$$E_B^\gamma = E_1(x_1^*, \gamma) + E_2(x_2^*, \gamma) \tag{16}$$

where $E_1(x_1^*, \gamma)$ and $E_2(x_2^*, \gamma)$ are computed in Equation (11) for $\gamma = 0$ and in Equations (13) to (15) for $\gamma = 1$.

We will study two possible scenarios depending on the universities' type in Region A and B. The main result that we find that, regardless of the universities' type, university duplication (and thus, increased competition) is not necessarily bad.

5.1 Non-research oriented universities

We analyze the case where both universities become non-research oriented, i.e. $\gamma = 0$. We will distinguish two possible situations depending on whether or not the two universities competing in Region B face the same cost of acquiring quality. In addition, we discard some less appealing resulting equilibria in the admission decision. Thus, we focus on the case where provided that both universities become non-research oriented then, the university with the lowest cost of acquiring quality sets the highest admission standard, that is, $x_1^* > x_2^*$.

Suppose first that the two universities located in Region B face the same cost of acquiring quality, i.e. $\alpha_1 = \alpha_2 = \alpha$. We denote α_B the total cost of acquiring quality in Region B, that is, $\alpha_B = 2\alpha$. Next we compare the aggregate excellence achieved in Region B with the aggregate excellence achieved in Region A. From (11) and (16) we have that $E_B^0 = \frac{17}{16}\left(\frac{1-\alpha_B}{2}\right)^2$. Thus it is clear from (5) that $E_A^0 \leq (\geq) E_B^0$ if and only if $\alpha_A \geq (\leq)\widetilde{\alpha}(\alpha_B) = \frac{(4-\sqrt{17})+\sqrt{17}\alpha_B}{4}$ where it can be checked that $\widetilde{\alpha}(\alpha_B) \leq \alpha_B$. That is, for Region B (with two non research oriented universities facing the same cost of acquiring quality) having a lower cost of acquiring quality than the university in region A is a sufficient condition to achieve a higher aggregate excellence than the university operating in Region A.

Now we turn to analyze the case where both universities in Region B face a different reputation cost. Then we analyze the following two cases, either $\alpha_A = \alpha_1 < \alpha_2$ or $\alpha_1 < \alpha_2 = \alpha_A$. The interpretation behind these two cases could be as follows. Suppose that initially Region A and B had just one university each of them, and that these two universities have the same reputation level (that is, either $\alpha_A = \alpha_1$ or $\alpha_A = \alpha_2$). Then, an additional university starts up in Region B facing a cost of acquiring quality different than that of the other two universities. Therefore whenever $\alpha_A = \alpha_1$ then the entering university is worse than the previous two (since $\alpha_1 < \alpha_2$) and whenever $\alpha_A = \alpha_2$ then the entering university is better than the previous two (since $\alpha_1 < \alpha_2$).

The following Proposition shows that whenever in Region B there is no specialization and both universities are non-research oriented then the comparison in aggregate excellence between both regions depends on the differential cost between both universities operating in Region B.

Proposition 6 *The following statements are true:*
(i) Let $\alpha_A = \alpha_1$*. Then* $E_A^0 \geq (\leq) E_B^0$ *if and only if* $\alpha_1 \geq (\leq)\alpha_L(\alpha_2)$*.*
(ii) Let $\alpha_A = \alpha_2$*. Then* $E_A^0 \geq (\leq) E_B^0$ *if and only if* $\alpha_1 \geq (\leq)\alpha_H(\alpha_2)$*.*

Proof. See the Appendix. ■

Observe that for any given (α_2, α_1) then $\alpha_L(\alpha_1, \alpha_2) < \alpha_H(\alpha_1, \alpha_2)$. Thus, Proposition 7 tells us that as the university operating in Region A becomes more reputable (α_A diminishes from $\alpha_A = \alpha_2$ to $\alpha_A = \alpha_1$) then the range of values of α_1 above which aggregate excellence in Region A is higher than in Region B increases.

Figure 2 below illustrate this result. It depicts $\alpha_L(\alpha_2)$ and $\alpha_H(\alpha_2)$. Observe that three regions emerges: Region 1, the set of pairs (α_2, α_1) such that $\alpha_1 \geq \alpha_H(\alpha_2)$, Region 2, the set of pairs (α_2, α_1) such that $\alpha_1 \in (\alpha_L(\alpha_2), \alpha_H(\alpha_2))$ and Region 3, that is, the set of pairs (α_2, α_1) such that $\alpha_1 \leq \alpha_L(\alpha_2)$.

Here Figure 2 (Region A vs. Region B: the non-research case)

Observe that, if the differential cost is low then either aggregate excellence in Region A will always be higher than in Region B (if both costs are high, Region 1 in Figure 2) or Region A will always be lower than in Region B (if both costs are low, Region 3 in Figure 2). However, as the differential cost increases (Region 2), then aggregate excellence in Region A will only be higher than in Region B if the cost of acquiring quality of university A is low (and equal to α_1). If it is not the case and the cost of acquiring quality of university A is high (and equal to α_2) then aggregate excellence in Region A is lower than in Region B.

Observe that if the entering university faces a reputation cost higher than that of the established universities in Region A and B, that is, if $\alpha_A = \alpha_1 < \alpha_2$ then as the differential cost increases then we might "jump" from a situation where $E_A^1 < E_B^1$ to other situation where $E_A^1 > E_B^1$. However, if the entering university faces a reputation cost lower than that of the established universities in Region A and B, that is, if $\alpha_A = \alpha_2 < \alpha_1$ then as the differential cost increases we might "jump" from a situation where $E_A^1 > E_B^1$ to other situation where $E_A^1 < E_B^1$.

5.2 Research oriented universities

Now we turn to analyze the case where both universities become research oriented, i.e. $\gamma = 1$. Again, we will distinguish two possible situations depending on whether or not the two universities competing in Region B face the same cost of acquiring quality.

Suppose first that the two universities located in Region B face the same cost of acquiring quality, i.e. $\alpha_1 = \alpha_2 = \alpha$. Next we compare the aggregate excellence achieved in Region B with the aggregate excellence achieved in Region A. From Remark 6 we have that that value of E_B^1 depends on whether G is above or below $\overline{G}(\alpha) = 4\alpha$. Note that since $\alpha_B = 2\alpha$ then $\overline{G}(\alpha) = 2\alpha_B$.

Observe first that, provided that both universities in Region B are research oriented then unless the cost of acquiring quality for university A is very low or the total research grant is very high, then aggregate excellence in Region A will always be higher than in Region B.

Proposition 7 *The following statements are true:*
(i) $E_B^1 > E_A^1$ *if* $\alpha_B \leq \alpha_A$*, for any* G*, or* $\alpha_B > \alpha_A$ *and* $G \leq \dfrac{\overline{G}(\alpha_A)}{2}$.
(ii) $E_B^1 < E_A^1$ *in all other cases.*

Proof. See the Appendix. ■

Several comments can be made here. First, for Region B, with two universities competing for research funds, having a lower cost of acquiring quality than the university in region A is a sufficient condition to achieve a higher aggregate excellence than the university operating in Region A. In other words, whenever there are no cost synergies among the institutions aggregated in university A, then this process of association among established universities does not result in a new institution (university A) with a higher aggregate excellence but rather increases the cost of acquiring one extra unit of quality regardless the amount of funds devoted to research. Second, for Region A, with "aggregated" universities, having a lower cost of acquiring quality than the universities in region B is a necessary but not sufficient condition to achieve a higher aggregate excellence than the universities operating in Region B. In addition, a high amount of research funds is required.

These results are in line with the analysis performed by Aghion et al. (2009). They found that competition for basic research funds induces universities to be more productive. In addition they show that, with sufficient autonomy, universities become better at research when the level of funding allocated by merit-bases competition is high enough.

Here Figure 3 (Region A vs. B: the research case)

Figure 3 above represents combinations (α_2, α_1) giving rise to the same value of $\overline{G}(\alpha_A)/2$. Recall that, $\overline{G}(\alpha_A)/2$ is the level of research grant such that the excellence in Region A and B coincides. Observe that, if the reputation cost of universities in both regions is very high, and unless the research grant is very high too, then the excellence in Region A will be higher than in Region B. Similarly, if the reputation cost of universities in both regions is very low, and unless the research grant is very low too, then the excellence in region A will be lower than that in region B. Finally observe that as the differential cost increases then we need a lower G to have $E_A^1 > E_B^1$. In other words, as the differential cost increases and for some fixed G we might "jump" from a situation where $E_A^1 > E_B^1$ to other situation where $E_A^1 < E_B^1$.

Let focus now on the case where both universities in Region B face a different reputation cost. Then we analyze the following two cases, either $\alpha_A = \alpha_1 < \alpha_2$ or $\alpha_1 < \alpha_2 = \alpha_A$.

The main result is that increased competition for resources and faculty candidates does not always imply higher aggregate excellence, i.e., E_B^1 is not always higher than E_A^1. In turn, aggregate excellence in Region B compared to that in Region A depends on the comparison among the reputation level of the universities operating in both markets and the total amount of the research funds, G. The following proposition summarizes the main result.

Proposition 8 *The following statements are true:*
(i) Let $\alpha_A = \alpha_1$. Then $E_A^1 \geq (\leq) E_B^1$ if and only if $G \geq (\leq) G_L(\alpha_1, \alpha_2)$.
(ii) Let $\alpha_A = \alpha_2$. Then $E_A^1 \geq (\leq) E_B^1$ if and only if $G \geq (\leq) G_H(\alpha_1, \alpha_2)$.

Proof. See the Appendix. ■

Observe that for any given (α_2, α_1) then $G_L(\alpha_1, \alpha_2) < G_H(\alpha_1, \alpha_2)$. Thus, Proposition 10 tells us that as the university operating in Region A becomes more reputable (α_A diminishes from $\alpha_A = \alpha_2$ to $\alpha_A = \alpha_1$) then the range of values of G above which aggregate excellence in Region A is higher than in Region B increases.

Here Figure 4 (Region A vs. Region B: the research case (II))

Figure 4a above represents combinations (α_2, α_1) giving rise to the same value of $G_L(\alpha_1, \alpha_2)$. Recall that, if $\alpha_A = \alpha_1$ then $G_L(\alpha_1, \alpha_2)$ is the level of research grant such that the excellence in Region A and B coincides. As it can be checked from proposition above, $G_L(\alpha_1, \alpha_2)$ is increasing with both α_2 and α_1. Figure 4b above represents combinations (α_2, α_1) giving rise to the same value of $G_H(\alpha_1, \alpha_2)$. Recall that, if $\alpha_A = \alpha_2$ then $G_H(\alpha_1, \alpha_2)$ is the level of research grant such that the excellence in Region A and B coincides. As it can be checked from proposition above, $G_H(\alpha_1, \alpha_2)$ is increasing with both α_2 and α_1.

Some additional comments can be made here. First we find that if the reputation cost of both universities located in Region B (both α_1 and α_2) is high, and unless the research grant is very high too, then the excellence in Region A will be higher than the aggregate excellence achieved in Region B. Similarly, if the reputation cost of both universities operating in Region B is very low (both α_1 and α_2), and unless the research grant is very low too, then the excellence in region A will be lower than that in Region B. Observe that this result is true regardless of whether or not the entering university faces a reputation cost higher than that of the established universities in Region A and B. That is, regardless of whether $\alpha_A = \alpha_1 < \alpha_2$ or $\alpha_A = \alpha_2 < \alpha_1$.

Second, and more interesting, we find that the effect of an increase in the differential cost between the two universities operating in Region B on the comparison in excellence between Region A and B depends on whether the entering university faces a reputation cost higher than that of the established universities in Region A and B. Namely, if the entering university faces a reputation cost higher than that of the established universities in Region A and B, that is, if $\alpha_A = \alpha_1 < \alpha_2$ then as the differential cost increases then we need a lower G to have $E_A^1 > E_B^1$. In other words, as the differential cost increases and for some fixed G we might "jump" from a situation where $E_A^1 < E_B^1$ to other situation where $E_A^1 > E_B^1$. However, if the entering university faces a reputation cost lower than that of the established universities in Region A and B, that is, if $\alpha_A = \alpha_2 < \alpha_1$ then as the differential cost increases then we need a higher G to have $E_A^1 > E_B^1$. That is, as the differential cost increases and for some fixed G we might "jump" from a situation where $E_A^1 > E_B^1$ to other situation where $E_A^1 < E_B^1$.

The main result we find in the comparison between aggregate excellence in Region A and B is that, regardless of the type of the two universities in Region B (research and non-research oriented) it is not always true that aggregate excellence in that region is always higher than in Region B. In fact, if the cost of acquiring quality for the university in region A is not very high, then aggregate excellence is higher there than in Region B.

6 Concluding Remarks

In this paper we analyze whether higher education providers, while pursuing maximum aggregate excellence, should launch new universities or should encourage the existing ones to form associations. We focus on the role of the type of universities (research vs. non-research oriented), the amount of research funds and the differential reputation cost among universities on higher education providers' choice.

Our main result is that it is not always true that aggregate excellence in the higher education market where there are universities competing is always higher than in the higher education market where there are universities associated. In addition we find that if the entering university faces a reputation cost higher than that of the established universities, then as the differential cost increases then we might "jump" from a situation where aggregate excellence in the higher education market where there are universities associated is lower than in the higher education market where there are universities competing to the opposite situation where the reverse is true. However, if the entering university faces a reputation cost lower than that of the established universities, then as the differential cost increases we might "jump" from a situation where aggregate excellence in the higher education market where there are universities associated is higher than in the higher education market where there are universities competing to the opposite situation where the reverse is true.

Since our model is quite specific we discuss now the robustness of the results to alternative assumptions. First, we have assume that there is not reward for teaching. This assumption can be justified by the fact that teaching quality, unlike research, is difficult to assess. Moreover, whereas the quality of research is comparable across academics in the same field, measures of teaching quality are often institution specific, and thus less comparable. Second, we assume that the fixed component of the university's net profit per candidate hired is equal to zero. It is easy to show that the optimal admission standard, may depend on this fixed component. In particular, the university i's optimal admission standard is decreasing with it. As such, the higher the fixed component, the lower the university's optimal admission standar, x_i^*. Thus, we can think of the optimal admission standard in the paper as an upper bound of the possible admission standard that may be set by universities in our model specification. However, it may happen that the admission standard does not depend on that fixed component for some parameter configuration provided that the university is research oriented.

Finally we think that the results presented here are relevant to several recent debates in the literature on the university governance. In particular it is specially relevant for Europe where some governments are implementing policies, in particular creating incentives for joint proposals among different universities, with the aim of changing the position of their higher education institutions in the current international hierarchy. Our results therefore provide support for policies that promote greater competition among universities whenever research expenditures are not sufficiently high.

7 Appendix

Proof. of Proposition 1: Consider first university 1. From Equations (UP) and (9) we have that, for any $x_2 \geq 0$, its excellence function is:

$$E_1(x_1, x_2) = \begin{cases} 0 & \text{if} \quad x_1 = 0 \\ (1-\delta)(1-x_1)x_1 + \delta(G-\alpha_1)x_1 & \text{if} \quad x_1 > 0. \end{cases} \tag{17}$$

Under (A.1) its best reply of university is $b_1(x_2) = \frac{(1-\delta)+\delta(G-\alpha_1)}{2(1-\delta)}$. Consider now university 2. From Equations (UP) and (8) its excellence function for any $x_1 \geq 0$ is:

$$E_2(x_1, x_2) = \begin{cases} x_2(\frac{1-x_2}{2}) - \delta\alpha_2 x_2 & \text{if} \quad x_2 \geq x_1 = 0 \\ x_2(x_1 - x_2) - \delta\alpha_2 x_2 & \text{if} \quad 0 \leq x_2 < x_1 \\ -\delta\alpha_2 x_2 & \text{if} \quad x_2 \geq x_1 > 0. \end{cases} \tag{18}$$

If $x_1 = 0$, the best reply of university 2 is $x_2 > 0$ since $x_2(\dfrac{1-x_2}{2}) - \delta\alpha_2 x_2 > 0$. In particular, $b_2(0) = \frac{1-2\delta\alpha_2}{2}$. We check that for any $x_1 > 0$ university 2 will never set $x_2 \geq x_1$. Thus, from Equation (18) its best reply is:

$$b_2(x_1) = \begin{cases} \frac{x_1 - \delta\alpha_2}{2} & \text{if} \quad x_1 > \alpha_2 \\ 0 & \text{if} \quad 0 < x_1 \leq \alpha_2 \\ \frac{1-2\delta\alpha_2}{2} & \text{if} \quad x_1 = 0. \end{cases} \tag{19}$$

Thus the unique equilibrium is $x_1^* = \frac{(1-\delta)+\delta(G-\alpha_1)}{2(1-\delta)}$ and $x_2^* = \frac{(1-\delta)(1-2\delta\alpha_2)+\delta(G-\alpha_1)}{4(1-\delta)}$. ■

Proof. of Proposition 2: (i) Suppose that there is an equilibrium in which $x_i = x_j = x$. If $x_j = x > 0$, from equations (7) and (10) we have:

$$E_i(x_i, x) = \begin{cases} x_i(\dfrac{1-x}{2} + x - x_i) - \alpha_i x_i & \text{if} \quad x_i < x \\ x(\dfrac{1-x}{2}) - \alpha_i x & \text{if} \quad x_i = x \\ x_i(\dfrac{1-x_i}{2}) - \alpha_i x_i & \text{if} \quad x_i > x. \end{cases} \tag{20}$$

Observe that $E_i(x_i, x)$ is continuous in x_i. Note also that, for any value of x there is always a profitable deviation: i) If $0 < x < \frac{1}{2} - \alpha_i$, then university i has incentives to deviate and set $x_i > x$ since $\lim\limits_{x_i \to x} \frac{\partial E_i}{\partial x_i} |_{x_i > x} > 0$, ii) If $x \geq \frac{1}{2} - \alpha_i$ then university i has incentives to deviate and set $x_i < x$ since $\lim\limits_{x_i \to x} \frac{\partial E_i}{\partial x_i} |_{x_i < x} < 0$. Finally, if $x_j = x = 0$, then university i has always incentives to deviate and set $x_i > 0$ since, from Assumption 1, $\lim\limits_{x_i \to 0} \frac{\partial E_i}{\partial x_i} |_{x_i > x} > 0$. (ii) and (iii) From Equation (20) we can check first that $E_i(x_i, x_j)$ is concave in each of the different intervals. In addition, from (A.1) the following two inequalities hold: $\lim_{x_i \to 0} \frac{\partial E_i}{\partial x_i} \mid_{x_i < x_j} > 0$ and $\lim_{x_i \to 1} \frac{\partial E_i}{\partial x_i} \mid_{x_i > x_j} < 0$. However the sign of both $\lim_{x_i \to x_j} \frac{\partial E_i}{\partial x_i} \mid_{x_i < x_j}$ and $\lim_{x_i \to x_j} \frac{\partial E_i}{\partial x_i} \mid_{x_i > x_j}$ depends on the value of x_j. In particular, if $x_j < \frac{1-2\alpha_i}{3}$ then $\lim_{x_i \to x_j} \frac{\partial E_i}{\partial x_i} \mid_{x_i < x_j} > 0$ and $\lim_{x_i \to x_j} \frac{\partial E_i}{\partial x_i} \mid_{x_i > x_j} > 0$ and thus the best reply of university i, $b_i(x_j) = \frac{1-2\alpha_i}{2}$ which is higher than x_j. If $x_j > \frac{1-2\alpha_i}{2}$ then $\lim_{x_i \to x_j} \frac{\partial E_i}{\partial x_i} \mid_{x_i < x_j} < 0$ and $\lim_{x_i \to x_j} \frac{\partial E_i}{\partial x_i} \mid_{x_i > x_j} < 0$ and thus $b_i(x_j) = \frac{1+x_j-2\alpha_i}{4}$ which is lower than x_j. Finally note that if $x_j \in (\frac{1-2\alpha_i}{3}, \frac{1-2\alpha_i}{2})$ then $\lim_{x_i \to x_j} \frac{\partial E_i}{\partial x_i} \mid_{x_i < x_j} < 0$ and $\lim_{x_i \to x_j} \frac{\partial E_i}{\partial x_i} \mid_{x_i > x_j} > 0$. By comparing the excellence function of university i evaluated at both $x_i = \frac{1-2\alpha_i}{2}$ and $x_i = \frac{1+x_j-2\alpha_i}{4}$ it can be checked that $b_i(x_j) = \frac{1-2\alpha_i}{2}$ (resp. $\frac{1+x_j-2\alpha_i}{4}$) if $x_j \leq$ (resp. $\geq$)$\widetilde{x}_j(\alpha_i)$ where $\widetilde{x}_j(\alpha_i) = (\sqrt{2}-1)(1-2\alpha_i)$. Thus, the best reply of university i is:

$$b_i(x_j) = \begin{cases} \frac{1-2\alpha_i}{2} & if \quad x_j \leq \widetilde{x}_j(\alpha_i) \\ \frac{1+x_j-2\alpha_i}{4} & if \quad x_j \geq \widetilde{x}_j(\alpha_i) \end{cases} \tag{21}$$

From (21) there are two possible equilibria. The first one, where $x_1^* = \frac{1-2\alpha_1}{2}$ and $x_2^* = \frac{(3-2\alpha_1-4\alpha_2)}{8}$ and thus $x_1^* > x_2^*$ always exists as $x_2^* < \widetilde{x}_2(\alpha_1)$. In addition a second equilibria, $x_1^* = \frac{(3-2\alpha_2-4\alpha_1)}{8} < x_2^* = \frac{1-2\alpha_2}{2}$, arises if an only if $x_1^* < \widetilde{x}_1(\alpha_2)$ or equivalently $\alpha_1 > \widehat{\alpha}_1(\alpha_2)$ where $\widehat{\alpha}_1(\alpha_2) = \frac{11-8\sqrt{2}+2(8\sqrt{2}-9)\alpha_2}{4}$. Finally note that if $\alpha_1 = \alpha_2 = \alpha$ then both equilibria exist. This completes the proof. ■

Proof. of Proposition 4: From Equation (**??**) we can check first that $E_i(x_i, x_j)$ is concave in each of the different intervals. In addition, from (A.1): $\lim_{x_i \to 0} \frac{\partial E_i}{\partial x_i} \mid_{x_i < x_j} > 0$. Note that $\lim_{x_i \to 1} \frac{\partial E_i}{\partial x_i} \mid_{x_i > x_j} < 0$ if either $x_j < \widehat{x}_j(\alpha_i, G)$, where $\widehat{x}_j(\alpha_i, G)$ is such that $\frac{(1+\widehat{x}_j)^2}{\widehat{x}_j} = \frac{G}{\alpha_i}$, or $\frac{G}{4\alpha_i} < 1$. The sign of $\lim_{x_i \to x_j} \frac{\partial E_i}{\partial x_i} \mid_{x_i < x_j}$ and $\lim_{x_i \to x_j} \frac{\partial E_i}{\partial x_i} \mid_{x_i > x_j}$ also depends on the value of x_j. In particular, $\lim_{x_i \to x_j} \frac{\partial E_i}{\partial x_i} \mid_{x_i < x_j} = \lim_{x_i \to x_j} \frac{\partial E_i}{\partial x_i} \mid_{x_i > x_j} > 0$ if and only if $x_j < \frac{G}{4\alpha_i}$. Consider two cases: (a) $\frac{G}{4\alpha_i} < 1$ which implies that $\lim_{x_i \to 1} \frac{\partial E_i}{\partial x_i} \mid_{x_i > x_j} < 0$. If $x_j < \frac{G}{4\alpha_i}$ then $\lim_{x_i \to x_j} \frac{\partial E_i}{\partial x_i} \mid_{x_i < x_j} = \lim_{x_i \to x_j} \frac{\partial E_i}{\partial x_i} \mid_{x_i > x_j} > 0$ and thus the best reply of university i, $b_i(x_j) = -x_j + \sqrt{x_j \frac{G}{\alpha_i}}$ which is higher than x_j. If $x_j > \frac{G}{4\alpha_i}$ then $\lim_{x_i \to x_j} \frac{\partial E_i}{\partial x_i} \mid_{x_i < x_j} = \lim_{x_i \to x_j} \frac{\partial E_i}{\partial x_i} \mid_{x_i > x_j} < 0$ and thus $b_i(x_j) = -x_j + \sqrt{x_j \frac{G}{\alpha_i}}$ which now is lower than x_j. Thus, if $\frac{G}{4\alpha_i} < 1$ then the best reply of university i for any x_j is:

$$b_i(x_j) = -x_j + \sqrt{x_j \frac{G}{\alpha_i}}. \tag{22}$$

(b) $\frac{G}{4\alpha_i} > 1$. If $x_j < \widehat{x}_j$ then $\lim_{x_i \to 1} \frac{\partial E_i}{\partial x_i} \mid_{x_i > x_j} < 0$ thus the best reply of university i:

$b_i(x_j) = -x_j + \sqrt{x_j \frac{G}{\alpha_i}}$ which is higher than x_j. If $x_j \geq \widehat{x}_j$ then $\lim_{x_i \to 1} \frac{\partial E_i}{\partial x_i} |_{x_i > x_j} \geq 0$ and thus the best reply of university i, $b_i(x_j) = 1$. Thus, if $\frac{G}{4\alpha_i} > 1$ then the best reply of university i for any x_j is:

$$b_i(x_j) = \begin{cases} -x_j + \sqrt{x_j \frac{G}{\alpha_i}} & if \quad x_j < \widehat{x}_j(\alpha_i, G) \\ 1 & if \quad x_j \geq \widehat{x}_j(\alpha_i, G) \end{cases}. \tag{23}$$

Now, (i) Let $G > \overline{G}$. Then, from (23) for $i = 1, 2$ the unique equilibrium is $x_1^* = x_2^* = 1$. (ii) and (iii) Let $G < 4\alpha_1$. Then, from (22) for $i = 1, 2$ the unique equilibrium is $x_i^* = \dfrac{\alpha_j}{(\alpha_j + \alpha_i)^2} G$ for $i = 1, 2$. Finally, let $G \in (4\alpha_1, \overline{G})$ and then from (23) for university 1 and (22) for university 2, there exists some $\underline{G} = \frac{(\alpha_1+\alpha_2)^2}{\alpha_2}$ such that, for $G \geq \underline{G}$ the equilibrium is $x_1^* = 1$ and $x_2^* = -1 + \sqrt{\frac{G}{\alpha_2}}$ and for $G < \underline{G}$ the equilibrium is $x_i^* = \dfrac{\alpha_j}{(\alpha_j + \alpha_i)^2} G$ for $i = 1, 2$. ■

Proof. of Proposition 6: (i) Let $\alpha_A = \alpha_1$. Then from (5) and $\delta = 1$ we have that $E_A^0 = \left(\frac{1-\alpha_1}{2}\right)^2$. From (11) and (16) we have that $E_B^0 = \frac{1}{2}\left(\frac{1-2\alpha_1}{2}\right)^2 + \left(\frac{2\alpha_1+4\alpha_2-3}{8}\right)^2$. Thus it is clear that $E_A^0 \leq (\geq) E_B^0$ if and only if $\alpha_1 \geq (\leq) \alpha_L(\alpha_2) = \frac{1}{10}(3 - 4\alpha_2 - 2\sqrt{1 + 24\alpha_2 + 16(\alpha_2)^2}$. (ii) Let $\alpha_A = \alpha_2$. Then from (5) and $\delta = 1$ we have that $E_A^0 = \left(\frac{1-\alpha_2}{2}\right)^2$. From (11) and (16) we have that $E_B^0 = \frac{1}{2}\left(\frac{1-2\alpha_1}{2}\right)^2 + \left(\frac{2\alpha_1+4\alpha_2-3}{8}\right)^2$. Thus it is clear that $E_A^0 \leq (\geq) E_B^0$ if and only if $\alpha_1 \geq (\leq) \alpha_H(\alpha_2) = \frac{1}{18}(11 - 4\alpha_2 - 4\sqrt{7 - 10\alpha_2 + (\alpha_2)^2})$. ■

Proof. of Proposition 7: From Equation (6) we have that $E_A^1 = G - \alpha_A$ for any G. We consider the following two cases for α_A: (i) Let $\alpha_A \geq \alpha_B$ then if $G > \overline{G}(\alpha)$ (or, equivalently, $G > 2\alpha_B$), then from Remark 6 and (16) we have that $E_B^1 = G - \alpha_B$ and thus it is clear that $E_A^1 < E_B^1$. If $G < \overline{G}(\alpha)$ (or, equivalently, $G < 2\alpha_B$) then from Remark 6 and (16) we have that $E_B^1 = \frac{G}{2}$ and then $E_A^1 < E_B^1$ if and only if $G < \overline{G}(\alpha_A)/2$ (that is, $G < 2\alpha_A$). But recall that since $\alpha_A \geq \alpha_B$ then $2\alpha_A \geq 2\alpha_B$ and thus $E_A^1 < E_B^1$. Now let (ii) $\alpha_A < \alpha_B$. If $G > \overline{G}$, then from Remark 6 and (16) we have that $E_B^1 = G - \alpha_B$ and thus it is clear that $E_A^1 > E_B^1$. If $G < \overline{G}(\alpha)$ (or, equivalently, $G < 2\alpha_B$) then from Remark 6 and (16) we have that $E_B^1 = \frac{G}{2}$ and then $E_A^1 < E_B^1$ if and only if $G < \overline{G}(\alpha_A)/2$. ■

Proof. of Proposition 8: From Equation (6) we have that $E_A^1 = G - \alpha_A$ for any G. We consider the following two cases for α_A :

(i) Let $\alpha_A = \alpha_1$. If $G > \overline{G}$ then, from Equations (13) and (16) we have that $E_B^1 = G - \alpha_1 - \alpha_2$ and thus it is clear that $E_A^1 > E_B^1$. Now let $G \in (\underline{G}, \overline{G})$.

From Equations (14) and (16) we have that $E_B^1 = G - \alpha_1 + \alpha_2 - \sqrt{\alpha_2 G}$. Thus, from (A.1) it is always true that $E_A^1 > E_B^1$. Finally, assume that $G < \underline{G}$. Then, from equations (15) and (16) we have that $E_B^1 = \frac{(\alpha_1^2+\alpha_2^2)}{(\alpha_1+\alpha_2)^2}G$. Thus, $E_A^1 > E_B^1$ if and only if $G > G_L(\alpha_1, \alpha_2) = \dfrac{\underline{G}(\alpha_1, \alpha_2)}{2}$. (ii) Let $\alpha_A = \alpha_2$ and $G_H(\alpha_1, \alpha_2) = \begin{cases} \frac{(2\alpha_2-\alpha_1)^2}{\alpha_2} & if \quad \alpha_1 \leq \alpha_2/2 \\ \dfrac{\underline{G}(\alpha_1, \alpha_2)}{2}\dfrac{\alpha_2}{\alpha_1} & if \quad \alpha_1 \geq \alpha_2/2 \end{cases}$. If $G > \overline{G}$ then, from Equations (13) and (16) we have that $E_B^1 = G - \alpha_1 - \alpha_2$ and thus it is clear that $E_A^1 > E_B^1$. Now let $G \in (\underline{G}, \overline{G})$. From Equations (14) and (16) we have that $E_B^1 = G - \alpha_1 + \alpha_2 - \sqrt{\alpha_2 G}$. Now we can distinguish the following two cases: (ii.1) Let $\alpha_1 \geq \alpha_2/2$ then it can be checked that since $\frac{(2\alpha_2-\alpha_1)^2}{\alpha_2} < \underline{G}$ then it is always true that $E_A^1 > E_B^1$, now (ii.2) let $\alpha_1 \leq \alpha_2/2$ and then $E_A^1 > E_B^1$ if and only if $G > \frac{(2\alpha_2-\alpha_1)^2}{\alpha_2}$. Finally assume that $G < \underline{G}$. Then, from equations (15) and (16) we have that $E_B^1 = \frac{(\alpha_1^2+\alpha_2^2)}{(\alpha_1+\alpha_2)^2}G$. Again we can distinguish the following two cases: (ii.1) Let $\alpha_1 \geq \alpha_2/2$. Then $E_A^1 > E_B^1$ if and only if $G > \dfrac{\underline{G}(\alpha_1, \alpha_2)}{2}\dfrac{\alpha_2}{\alpha_1}$, now (ii.2) let $\alpha_1 \leq \alpha_2/2$ and then it can be checked that since $\dfrac{\underline{G}(\alpha_1, \alpha_2)}{2}\dfrac{\alpha_2}{\alpha_1} > \underline{G}$ then it is always true that $E_A^1 < E_B^1$. ■

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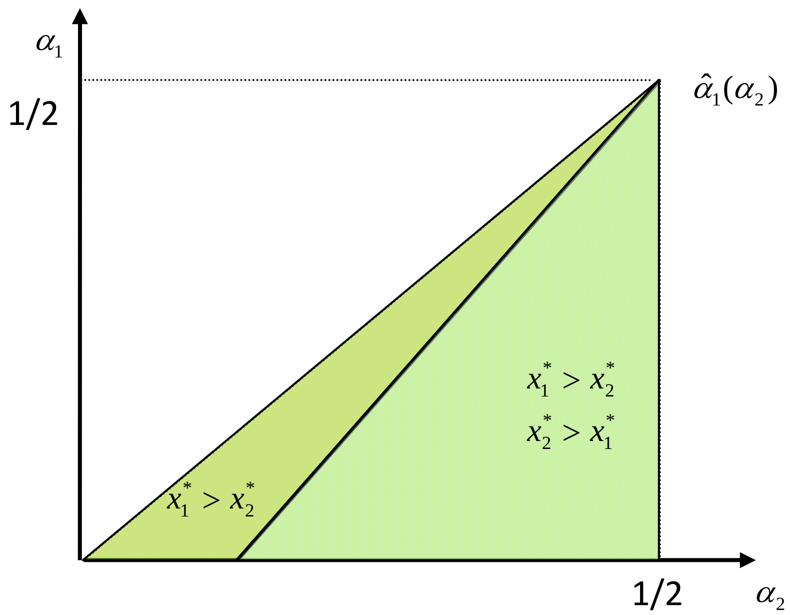


Figure 1: Non research universities equilibria

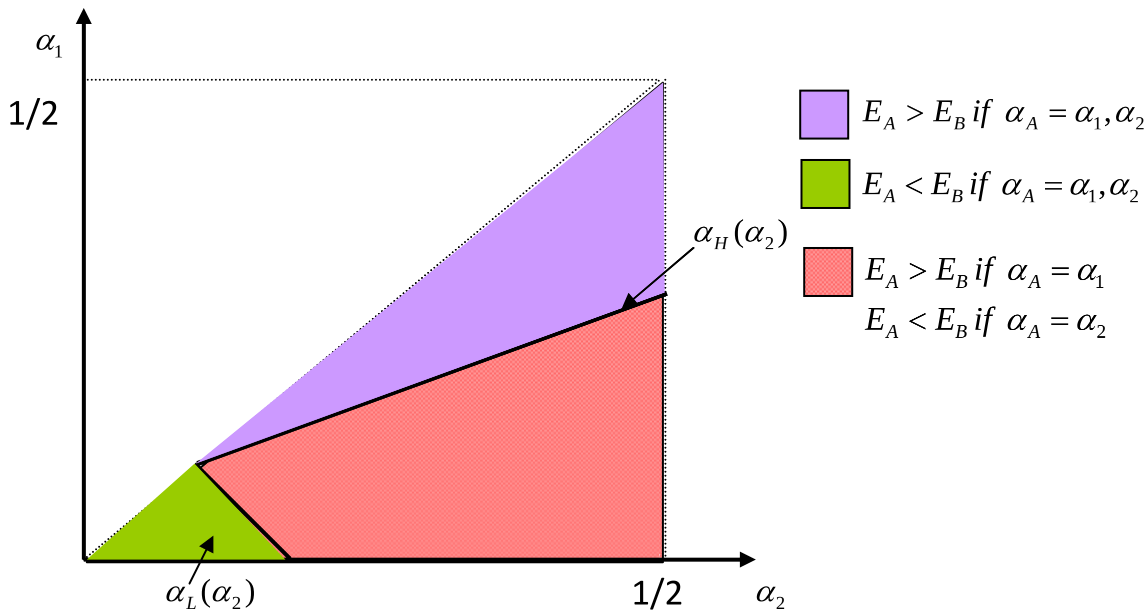


Figure 2: Region A vs. Region B. The non-research case

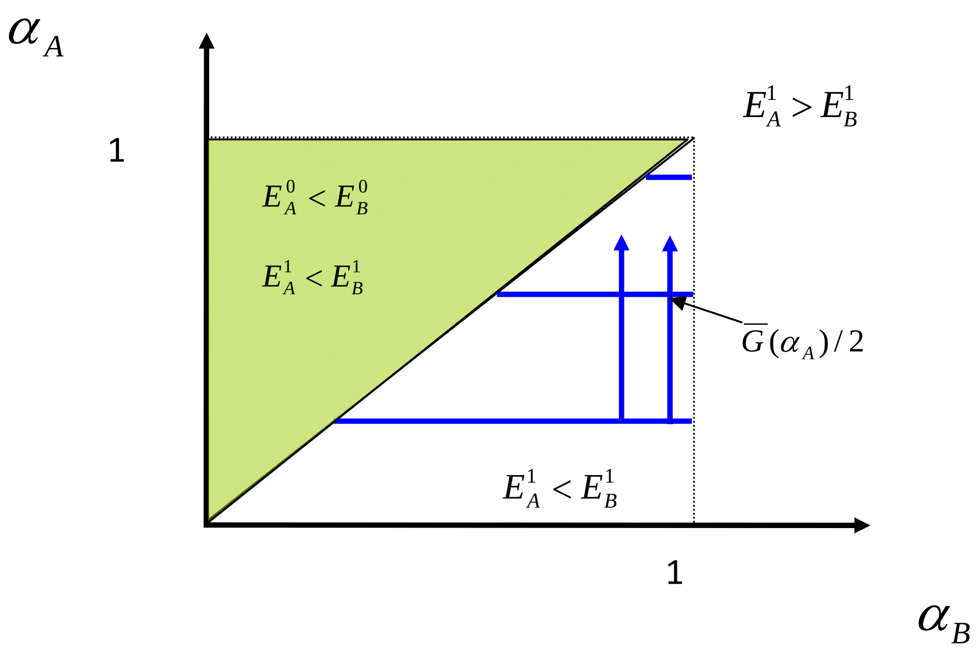
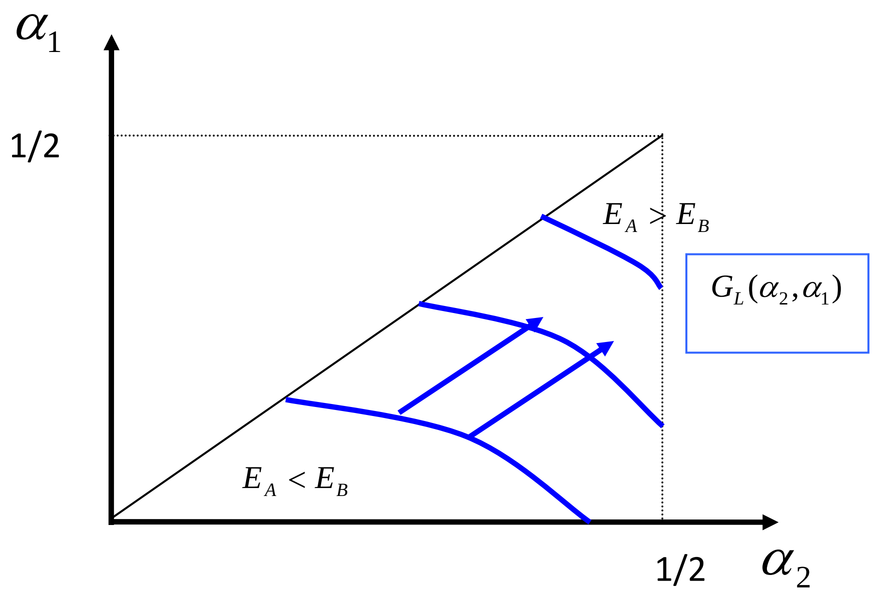
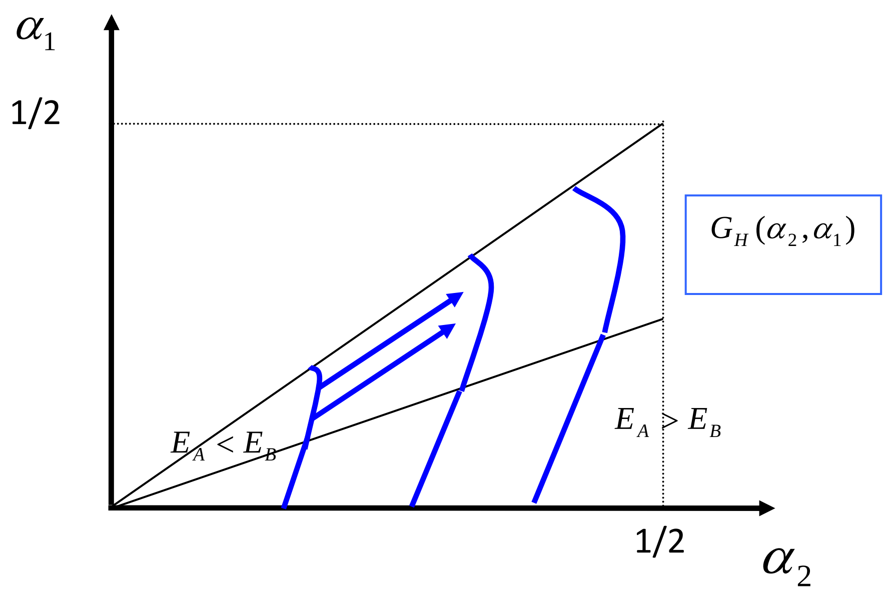


Figure 3. Region A vs. Region B: Both universities face the same cost



(a) Entering university is "bad" ($\alpha_A = \alpha_1$)



(b) Entering university is "good" ($\alpha_A = \alpha_2$)

Figure 4. Region A vs. Region B: the research case (II)