Research Article

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University Merging Process: A Guideline Proposal for Excellence-Enhancing

DOI 10.1515/bejeap-2015-0237

Published online July 2, 2016

Abstract: There is a recent trend toward encouraging universities to merge. This policy is based on the idea that mergers create synergy gains that enhance the prestige of universities by increasing their international visibility. However, this process may reduce competition for both research funds and professors in national higher education markets. This paper analyzes whether mergers among universities are optimal from an excellence perspective. We find that as the heterogeneity between the initial reputations of potentially merging institutions increases, the amount of funds required for mergers to achieve higher excellence than competition also increases.

Keywords: higher education, economics of science, university competition, university mergers

JEL Classification: H52, I23, I28, J24

1 Introduction

Merger processes among universities are increasingly attracting the interest of education policy makers. Countries such as Australia, Canada, China (with over 500 mergers until 2005), France, Norway, Sweden, the Netherlands and the UK carried out these initiatives in the 1990s and the early 2000s. Particular examples of mergers abound, such as UniverSud Paris in France, Leiden University in the Netherlands and Stockholm University in Sweden. However, this is only a sample of the entire list (see Skodvin 1999, among others, for a detailed elaboration of mergers in higher education).

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This growing interest in restructuring this market is driven mainly, on one hand, by increasing international competition in the higher education sector and, on the other hand, by the adverse impacts of reduced public funding. This trend is based on the idea that mergers enhance the excellence of universities and provide them with more visibility in international markets.¹ Mergers have been widely discussed in the literature. Specifically, a great deal has been written about the effects of mergers in industry on welfare (see Shapiro 2010 and references therein). There are also several works on higher education mergers based on case studies (see, among others, Skodvin 1999 cited above, or more recently, Johnes 2014 for a preliminary efficiency analysis on recent mergers in the English higher education market). Surprisingly, it is difficult to find clear theoretical policy guidelines regarding mergers in the public sector, particularly in the higher education sector. Moreover, most works have focused on the effect mergers have on product markets, and less attention has been paid to study suppliers' reactions to mergers. This makes this work both timely and relevant.

This paper contributes to this ongoing debate by addressing the following question: To what extent do mergers lead to higher excellence than competing universities? Mergers among universities immediately raise efficiency questions. First, although they might reduce costs, mergers also diminish the degree of competition for resources and professors, which negatively affects excellence. Second, by reducing competition, mergers may also lead to decreased faculty candidates' bargaining power as they face fewer outside options. Therefore, mergers might reduce universities' total salary expenditure, which, in turn, might positively affect university total excellence by making more funds available for other types of expenditures.

To address these issues, we model the higher education sector on the following basis. We consider the factor markets for universities. In doing so, we implicitly assume that the services universities provide are sold in international markets in which individual university decisions have little impact. Nonetheless, factors such as professors and resources are hired mostly for production within the national or

¹ As Goedegebuure (2012) points out, an increasing number of mergers and alliances can be described as prestige-inspired. One of the most well-known cases is the merger between Victoria University of Manchester and the Manchester University of Science and Technology to form the University of Manchester. In the 2013 Academic Ranking of World Universities (Shanghai Jiao Tong University 2013), the University of Manchester found itself in 41st position, rising from 53rd in 2005. Another good example of restructuring the system to better face global competition is the Danish case, where 12 universities and 13 government research centers were merged into 8 universities and 5 research centers.

country-level markets.² When analyzing professors, we adopt an approach similar to that of Rothschild and White (1995) regarding students. We argue that professors can be seen as both inputs and clients for the services provided by the university. As such, there are two important reasons that universities may compete for faculty candidates. On one hand, as inputs, professors are scarce resources required for the university production process. On the other hand, as clients, the faculty indirectly provides the university with the funds it needs to operate. In our model, universities differ in their initial reputations. They act as non-profit institutions, that is, they face a non-distributional constraint and have the goal of maximizing prestige or excellence subject to budget constraints. Universities maximize excellence growth by choosing the quality of incoming faculty members (vertical differentiation), which determines the amount of research resources that universities receive from government funding agencies and the amount of resources that are provided for teaching. This diversity of funding sources influences the universities' specialization regarding how to be financed. We analyze university performance in two different settings: in the first, two universities are competing for faculty candidates and resources, whereas in the second, there is just one merged university.³

We find that the relationship between the degree of heterogeneity of competing universities (measured by their reputation differential) and the amount of research funds plays a key role in determining the success or failure of mergers. First, the amount of research resources affects the degree of fund-seeking specialization of competing universities. Second, the degree of heterogeneity between competing universities modulates the level of exploitation of that specialization. In particular, greater heterogeneity reinforces specialization benefits in terms of the total increase in excellence in this competitive setting. Therefore, as the heterogeneity between competitors increases, the amount of

² Since 2000, the number of foreign students within OECD countries has increased by more than 50 % (see OECD 2008). However, though globalization is increasing academic mobility, academic labor markets remain very national (see Musselin 2004 for an empirical analysis of the European case). A more recent analysis (Franzoni, Scellato, and Stephan 2012) finds that the percentage of foreign scientists is 3.0 % in Italy, 5.0 % in Japan, and 7.3 % in Spain. There are, however, some exceptions to this pattern. In Switzerland and the US, approximately 50 % and 38.4 % of scientists, respectively, are foreign. In addition, on average, less than 1 % of total funds in Europe came from international sources in 2003 (see Eurostat 2007).

³ Duopoly could be one of the market structures that best captures local higher education markets. Even though, in reality, there might be more than two institutions, in most cases, there are not more than two of the same type (research-oriented or polytechnic institutions, etc.). In addition, this modeling approach is commonly accepted in the literature. See Del Rey (2001), among others, who also consider a duopoly when studying competition between universities.

funds required for a merger to maximize excellence growth increases. This is our main result. The intuition behind it is as follows. Suppose that the total amount of research grants is low. In this case, and interestingly, we find that there could be an equilibrium in which the universities specialize in the choice of funding sources, some compete for research funds, and others compete for teaching funds. In that case, a merger between universities could be detrimental because of the fact that, in this case, universities do not take advantage of their potential synergy gains. Thus, for an eventual merger process to guarantee higher excellence growth than competition, a larger amount of funding for research grants must be available. As more research funds become available, the previous gains from specialization disappear, and an extreme result in which universities compete mostly for research funds may emerge. If this is the case, a merger between universities guarantees the maximum increase in excellence, as they really take advantage of their potential synergy gains.

There are two strands of literature related to our work: the literature on university competition for students, resources and professors and the research on non-profit institutions. The first strand of literature studies the effects of competition between universities on welfare. Del Rey (2001) considers a model of university competition for students in which she investigates the strategic choice of universities between teaching and research activities. Her focus is on how the financial allocation between both activities can be controlled by a proper choice of the government's parameters. Similarly, Gary-Bobo and Trannoy (2008) conclude that whether competition leads to optimal outcomes depends on the incentives provided by governments through financing schemes. However, the authors concentrate on the education provision role of universities and leave research out of the scope of their analysis. In this paper, we consider university competition for resources and faculty candidates, and we do not examine competition for students. Aghion et al. (2009) focus on competition for resources and empirically show that university autonomy and competition are positively correlated with university output among both European and US public universities. Beath, Poyago-Theotoky, and Ulph (2012) study how the funding system influences the trade-off universities make between research and teaching. In their model, universities' budget constraint determines the type of higher education structure that emerges. In particular, the emergence of "research elites" universities and the differentiation between "polytechnic institutions" and "universities" is derived. Prüfer and Waltz (2013) address the relationship between a faculty's reputation and its competition for new candidates, which explicitly determines the optimal faculty size. Our paper complements their research by comparing the impact of competition and mergers on both the equilibrium quality standard and the total excellence growth. By doing

so, our analysis confirms that the number of universities operating in the academic labor market affects their salary expenditures. In the second strand of literature, Prüfer (2011) studies the factors that determine the success of mergers among non-profit institutions, that is, those prohibited both from making losses and from distributing potential profits to their owners. He shows that it is not possible to assess the net effects of a merger between two non-profits without considering the objectives of the involved owners. We concentrate here on the role of the initial reputations of universities and the amount of research funds in determining the success or failure of mergers.

The paper is organized as follows. Section 2 introduces the model. Section 3 characterizes the equilibria in the merger and competitive settings. Section 4 presents the results of the comparison between competition and mergers. Finally, Section 5 concludes.

2 The Model

In this section, we describe the behavior of the agents comprising the higher education market: faculty candidates and universities.

2.1 Faculty Candidates

We assume there is a continuum of faculty candidates who differ according to their productivity in teaching and research activities, θ . For convenience, we assume that candidates are uniformly distributed in the interval $[0,1]$. This productivity can also be interpreted as the candidates' relative value for the universities and, thus, cover a wide set of characteristics, such as methodological and writing skills and network relations (see Prüfer and Waltz 2013 for a similar assumption).⁴

Now, let $x_u \in [0,1]$ denote the minimum quality standard required by university u to incoming faculty candidates. That is, only those candidates whose productivity is above x_u are offered a position at university u . The salary scheme of the candidates is the sum of a fixed minimum wage, w , plus his/her own productivity, i.e., $w + \theta$. We assume that candidates' preferences are lexicographic: they always prefer higher wages, but, for the same wage, they prefer to work at the university with the higher minimum quality standard. This

⁴ Thus, we are implicitly assuming that teaching and research productivity are correlated. First, this is certainly the case for graduate studies (see Zaman 2004 for an extensive review on the empirical evidence on this relationship). Second, as will be shown below, explicitly modeling different type of productivities increases the complexity of the analysis without offering additional insights.

assumption captures two ideas. First, the willingness to accept a position is positively related to the academic standard of the university because of research spillover with other hired professors. Second, as a result of this, universities compete for candidates by setting high-quality standards.

2.2 Universities

Universities differ in many dimensions (missions, student clientele, etc.). In our model, institutions differ in their ability to capture highly productive candidates and resources. This is captured by an exogenously given reputation cost parameter $a_u \in (0, 1)$ so that the less-reputable university has a higher a_u . This means that less-reputable universities have to make a greater effort to attract a given level of quality.⁵ The goals of universities are not easy to define. Nevertheless, the pursuit of excellence appears to be the motivation of most university administrators and governing boards. University mission statements usually refer to teaching and research as means of fostering development or growth, among other targets. We assume that universities aim to maximize their prestige or excellence. In particular, we consider that this goal is closely related to the creation of research and the dissemination of knowledge through teaching.⁶ To achieve this objective, universities hire the most able faculty members and pursue the highest-quality academic and cultural environments.

To sharpen our analysis, we consider that universities aim to improve their present levels of excellence. Accordingly, E_u must be interpreted as university u 's increase in excellence during the next academic period. We believe that this is a

⁵ As noted by Graves, Marchand, and Thompson (1982), universities' reputations serve several related functions, including the one mentioned above. For instance, it can also be understood as the expertise of universities to supplement public funding with funds from private sources in order to attract more productive candidates. These may include, for example, income from endowments or alumni donations. For students, these reputations are suggestive of the skills and knowledge of faculty. Reputation also serves as a signal of trustworthiness to funding agencies. The assumption of an exogenous reputation parameter may seem unrealistic, and clearly, an interesting extension that we do not pursue in this paper would be to endogenize this parameter (Hidalgo-Hidalgo and Valera 2006 develop this idea in a rigorous model). However, this assumption is commonly accepted in the literature. See, among others, De Fraja (2011) and Epple, Romano, and Sieg (2006), who also assume that universities exogenously differ in productivity levels.

⁶ See Beath, Poyago-Theotoky, and Ulph (2012) for a similar assumption. For an in-depth analysis of universities' objective function, see Garvin (1980), Winston (1999), and Clotfelter (1999), among others. Alternatively, we could consider universities to be organizations whose aim is to maximize rents, that is, the difference between the university's total revenues and total costs. We comment on this issue in Section 5.

sensible approach because most universities incrementally introduce small reforms (hiring new faculty) instead of introducing large reforms in every academic period (firing most of the faculty, etc.). The increase in excellence E_u depends on two factors: the new human capital H_u and physical capital K_u . The former is captured by the quality-weighted number of incoming faculty members, i. e., $H_u = n_u \bar{\theta}_u$, where n_u denotes the number of hired candidates and $\bar{\theta}_u$ denotes the average productivity of all incoming faculty candidates at university u . The most natural interpretation of K_u is the value of university u 's infrastructure, which may include labs, research assistants, sabbaticals, pay for travel to conferences, the purchase of computer software or datasets, and the like. To simplify further, we propose the following objective function:

$$E_u = H_u + \delta K_u, \quad [1]$$

where $\delta \in (0, 1]$ measures the weight of physical capital on excellence.⁷ In this setting, universities set the quality standards x_u , which, as we see below, determines the number of candidates hired, n_u , the new human capital H_u and the resources for maintaining facilities, K_u .

Universities use government funding to pay for their activities; therefore, they maximize [1] subject to their total cost not exceeding their revenues. We assume that university revenues are provided by funding agencies, in particular, the total funds that each university u receives come from two sources. The first source is related to the number of hired faculty, m_u , where r is an exogenous parameter that captures the resources paid to the university per lecturer. Therefore, teaching funds are increasing in the number of faculty candidates hired or in the total number of students for a fixed student-to-lecturer ratio (it is, in fact, quite common that universities receive some amount per student to finance their activities). Because this paper focuses on university hiring policies, we do not analyze student behavior. That is, we implicitly assume that by hiring the best lecturers and providing the best campus facilities, universities can attract more students, thereby allowing them to select the best students.⁸

The second source of funds is based on research activity. We denote by g the total grants available from funding agencies to finance research. This scheme

⁷ This specification is bound to yield extreme results. However, as discussed later in this paper, this setting in general does not lead to corner solutions. When it occurs, the results shall be interpreted in that manner. Finally, observe that universities' preferences between human capital and physical capital does not depend on their type.

⁸ Winston (1999) and Epple, Romano, and Sieg (2006) use a similar argument. Siow (1997) finds that universities with more successful researchers have larger shares of out-of-state and foreign students.

resembles the research funding models currently used, according to which funds are provided by research agencies on the basis of research proposals sent in by research teams.⁹ Thus, we assume that g will be allocated competitively among the universities operating in the market and that each university u receives a proportion p_u of g . In particular, this competition for grant money is modeled as a contest. That is, as will be explained in Section 3 below, p_u is a function of the quality standards set by the universities operating in the market. Therefore, the total revenues of university u , R_u , are as follows:

$$R_u = m_u + gp_u. \quad [2]$$

Each university spends these resources on maintaining facilities K_u , seeking high-quality faculty candidates and paying salaries. The total salary expenditure of university u is denoted by S_u . It is important to note that the salary scheme (and, thus, the university's salary bill) is assumed to be the same regardless of the number of universities operating in the market. That is, we do not impose a different specification for the salary scheme in the merger and competitive settings, which resemble a monopsony and an oligopsony, respectively (see Boal and Ransom 1997 for a similar way of modeling the academic labor market). Interestingly, we still find that the equilibrium total salary expenditure in each of the settings coincides with the standard result. Namely, the equilibrium salary expenditure in the merger setting is lower than or equal to that under competition. The intuition behind this can be found by looking at the candidates' bargaining power in the two settings: to the extent that a merger among universities reduces the number of higher education institutions at the local level, the outside options for faculty candidates are reduced, leading to a saving on the total salary bill (see Section 3 below and Ransom 1993 for related empirical evidence).¹⁰ As we mentioned above, we assume that hiring the best candidates, which is performed by setting a minimum quality standard, x_u , to

⁹ Hicks (2012) reports some data on the share of university budgets related to performance-based research systems for several countries. Indeed, according to the European Commission (2008), in most European countries, this funding accounts for an important share of the university research budget and can exceed 50 % in some cases. More importantly, the proportion of funds distributed through competitive grant schemes (i. e., research councils) is increasing relative to the funding allocated to formulas and other direct (core) funding schemes.

¹⁰ Note that, as long as a lower university total salary bill for publicly funded universities might imply a lower load for taxpayers, this result could be regarded as an additional advantage of mergers. We do not consider here the effects of mergers on agents other than universities and faculty candidates because our focus is not on comparing different general tax subsidy schemes but rather on the trade-off faced by policy makers when deciding whether to merge universities from an excellence point of view.

incoming candidates is costly and inversely related to the university's reputation. This is motivated by the fact that faculty candidates use such reputations as proxies for the quality of the research and teaching environments at specific universities. In particular, $C_u(x_u)$ denotes that cost, which is equal to $a_u x_u$.¹¹ Thus, the university budget constraint is as follows:

$$K_u + S_u + C_u = R_u. \quad [3]$$

Recall here that, similar to the university objective function, the university budget constraint must be interpreted as university u 's increase in its total cost and revenues during the next academic period. Consequently, eq. [3] does not include either the salary expenditure or the revenues corresponding to existing faculty members.

Universities balance those funds coming from teaching activities (m_u) against those funds coming from research activities ($p_u g$) when selecting their quality standards. There is a trade-off involved: setting a high-quality standard attracts more research funds but fewer teaching resources. Universities set their quality standard, x_u , to maximize their increase in excellence subject to the budget constraint:

$$\begin{array}{ll} \text{Max}_{\{x_u\}} & E_u = H_u + \delta K_u \\ \text{s.t.} & K_u + S_u + C_u = R_u. \end{array} \quad [\text{UP}]$$

Let x_u^* denote the equilibrium quality standard set by university u . Recall that only those candidates whose productivity is above x_u are offered a position at university u . Observe that we do not exclude the possibility of universities becoming so selective that they do not hire any new candidate for the next academic period, that is, $x_u^* = 1$. This result should be interpreted as an extreme case in which universities decide not to expand the size of their faculties in the next period. If this is the case, then students would be taught by the already existing faculty members incurring no additional salary expenditures.

In what follows, we assume that a_u , i. e., the cost of acquiring one extra unit of quality, is sufficiently low to guarantee that the equilibrium quality standard is strictly positive. Otherwise, corner solutions would arise with universities

11 Therefore, it captures monetary costs other than wages related to hiring top candidates, for instance, administration costs, substitution of lecturers for researchers, etc. See Ehrenberg, Rizzo, and Jakubson (2007) for an in-depth analysis of the growing costs of funds for new faculty. Observe that the opportunity cost of seeking candidates might be higher for the most reputable universities. Nevertheless, and following Graves, Marchand, and Thompson (1982), we assume that the total cost of setting any quality standard is greater for the least reputable university.

providing no quality at all or hiring the entire population of new faculty candidates, which does not seem to be reasonable. To rule out this possibility, we establish Assumption 1, which means that starting from $x_u = x_v = 0$ the marginal benefit of raising x_u is positive. Let first $t \geq 0$ denote the fixed component of the university's net profit per hired candidate, i. e., $t = r - w$.

Assumption 1 (A.1): $a_u < g - t$.

We now consider two settings. In the first setting, two universities, university 1 and university 2, are competing for resources. We compute the Nash equilibrium for this particular university market structure. In the second setting, universities are encouraged to merge. We next focus on comparing total excellence growth between the competitive and merger settings.

3 Equilibrium in the Merger and Competitive Settings

In this section, we analyze how the university's quality decision depends on whether the higher education market is characterized by competition or mergers.

3.1 Two Competing Universities

We analyze a game in which two universities simultaneously choose the quality standards required for incoming faculty candidates, x_1 and x_2 . Because the focus is on the behavior of universities operating in the higher education market rather than on whether to enter into this market, we believe this approach is more appropriate than modeling sequential decisions. An important feature in this setting is the financing scheme. The proportion of total research grants that each university u can obtain given its competitors' quality standard, x_v , is denoted by $p_u(x_u, x_v)$, for $u \neq v$ and $u = 1, 2$ and depends on the relative quality standards set by both universities:

$$p_u(x_u, x_v) = \begin{cases} \frac{x_u}{x_u + x_v} & \text{if } x_u + x_v > 0 \\ 0 & \text{if } x_u + x_v = 0. \end{cases} \quad [4]$$

This reward structure can be interpreted as a particular tournament in which there is a rank-order payment scheme. These are often used as allocation mechanisms; see Lazear and Rosen (1981). Indeed, Gautier and Wauthy (2007) find that

the optimal allocation of resources among departments should be based on the relative performance of their research projects. Thus, we assume that universities always receive a proportion of the award, g , as long as they set a positive quality standard. Note that the funding agency always fully allocates g except in the case when both universities choose the lowest quality standard. If this occurs, no award is provided. Recall that each university receives funds depending on the number of hired faculty, m_u , for $u \neq v$ and $u = 1, 2$. Observe that given candidates' preferences, when admitted to both universities, a faculty candidate chooses to work at the one with the highest quality standard. Therefore, it is immediate that, as candidates' productivity is uniformly distributed and they are hired at national local markets, increasing university quality standard x_u implies increasing the average productivity of all incoming faculty candidates $\bar{\theta}_u$ while reducing university hired faculty n_u . In particular, $\bar{\theta}_u$ is as follows:

$$\bar{\theta}_u(x_u, x_v) = \begin{cases} \frac{x_v + x_u}{2} & \text{if } x_u < x_v \\ \frac{1 + x_u}{2} & \text{if } x_u \geq x_v \end{cases} \quad [5]$$

and the partition of candidates between both universities is as follows:

$$n_u(x_u, x_v) = \begin{cases} x_v - x_u & \text{if } x_u < x_v \\ \frac{1 - x_u}{2} & \text{if } x_u = x_v \\ 1 - x_u & \text{if } x_u > x_v. \end{cases} \quad [6]$$

Hence, the university u 's optimization problem given its competitor's quality standard, x_v , $u \neq v$, is

$$\begin{aligned} \max_{\{x_u\}} \quad & E_u(x_u, x_v) = H_u(x_u, x_v) + \delta K_u(x_u, x_v) \\ \text{s.t.} \quad & K_u + S_u + C_u = R_u(x_u, x_v). \end{aligned} \quad [7]$$

We now proceed to analyze the optimal quality decisions of both universities. The Nash equilibrium between universities is the combination of their best response functions. Each university solves the maximization problem described in eq. [7], where $R_u(x_u, x_v)$ is given by eq. [2] and $p_u(x_u, x_v)$ and $n_u(x_u, x_v)$ are given by eqs [4] and [6], respectively.

As previously commented, there is a trade-off involved while setting the quality standard, x_u . On one hand, if universities focus on competing for research resources g , then, as it can be easily verified from eqs [4] to [7], they will pursue a high p_u for which a high minimum quality standard x_u is required, which entails an increase in C_u . On the other hand, if universities focus on competing for teaching resources, then they will pursue a high n_u for which a

low minimum quality standard is required. This, in turn, implies a reduction in C_u . Therefore, university reputation (through its effect on C_u) plays a crucial role when universities set x_u while competing for research resources, whereas it plays a less relevant role when universities compete for teaching funds.

Without loss of generality, we consider university 1 to be more reputable than university 2; that is, $a_1 < a_2$. Thus, we can define the heterogeneity between the universities as the differential reputation cost between them, $a_2 - a_1$. As we will see below, this differential cost affects universities' choices in terms of fund-seeking specialization and the extent to which this specialization is exploited in terms of excellence production. By fund-seeking specialization, we refer to the scenario where one university competes mainly for research resources and the other competes mainly for teaching resources.

We first show that, regardless of the amount of research grants and of universities' reputation, there is no symmetric equilibrium in which both universities admit at least some candidates but not all of them. Lemma 1 presents this result.

Lemma 1: Let (x_1^*, x_2^*) denote the optimal quality standards set by each university in equilibrium. There is no equilibrium where $x_1^* = x_2^* = x$ and $x \in (0, 1)$.

Proof: Using eqs [2] and [3], we solve the budget constraint for K_u . By substituting it in university u 's objective function in eq. [1], we can rewrite it as follows:

$$E_u(x_u, x_v) = ((1 - \delta)\bar{\theta}_u(x_u, x_v) + \delta t)n_u(x_u, x_v) + \delta(gp_u(x_u, x_v) - a_u x_u).$$

Suppose now that there is an equilibrium in which $x_u = x_v = x$. If $x_v = x > 0$, then from eqs [4] to [6], the university u 's objective function [8], given its competitor's quality standard, x is as follows:

$$E_u(x_u, x) = \begin{cases} ((1 - \delta)\left(\frac{x + x_u}{2}\right) + \delta t)(x - x_u) + \delta\left(g\left(\frac{x_u}{x_u + x}\right) - a_u x_u\right) & \text{if } x_u < x \\ ((1 - \delta)\left(\frac{1 + x}{2}\right) + \delta t)\left(\frac{1 - x}{2}\right) + \delta\left(\frac{g}{2} - a_u x\right) & \text{if } x_u = x \\ ((1 - \delta)\left(\frac{1 + x_u}{2}\right) + \delta t)(1 - x_u) + \delta\left(g\left(\frac{x_u}{x_u + x}\right) - a_u x_u\right) & \text{if } x_u > x. \end{cases} \quad [9]$$

It is clear that by evaluating $E_u(x_u, x)$ at $x_u = x$, we obtain

$$\begin{aligned} \delta\left(\frac{g}{2} - a_u x\right) &< \left((1 - \delta)\left(\frac{1 + x}{2}\right) + \delta t\right)\left(\frac{1 - x}{2}\right) + \delta\left(\frac{g}{2} - a_u x\right) \\ &< \left((1 - \delta)\left(\frac{1 + x}{2}\right) + \delta t\right)(1 - x) + \delta\left(\frac{g}{2} - a_u x\right). \end{aligned} \quad [10]$$

Then, (x, x) can never be an equilibrium because setting any $x_u + \varepsilon$ with a sufficiently small ε always increases the excellence of university u .

If $x_v = 0$, then it is clear from eq. [9] and (A.1) that the best reply of university u is to set some $x_u > 0$. ■

Observe that this result does not depend on the reputation cost of both universities, a_u for $u = 1, 2$. That is, regardless of whether they are symmetric in reputation costs (i. e., $a_1 = a_2$) or not there is not symmetric equilibrium in which both universities admit at least some new candidates but not all of them, i. e., $x_1^* = x_2^* = x$ and $x \in (0, 1)$.

Next, we characterize the optimal quality standards set by both universities in equilibrium, x_1^* and x_2^* . To guarantee the existence of an interior equilibrium (that is, an equilibrium where at least one university admits some new candidates during the next academic period $x_u^* < 1$), we need to restrict the set of values that the research grant can take.

Assumption 2 (A.2): Let $g \in (\underline{g}, \bar{g})$ where $\underline{g} = \frac{2t(a_1 + a_2 + 2t)^2}{2t(a_2 + t) + (a_1 - a_2)^2}$ and $\bar{g} = 4(a_2 + t)$.

We first comment on the lower bound for g . This requirement guarantees equilibrium existence. Recall that universities, when deciding their optimal quality standards for the next period x_u^* , face a trade-off: setting a high-quality standard attracts more research funds but fewer teaching resources. This assumption ensures that revenues from research must be high enough to balance the loss in funds from teaching as x_u increases. It is interesting to analyze the role of some component of the teaching funds, t on $\underline{g}$. Note that if $t > 0$; then, both universities have incentives to lower their quality standards below that of their competitor to hire more candidates. Therefore, the existence of an equilibrium is not guaranteed in this case. To avoid this, we require the research grant amount to be sufficiently high. As commented above, the sources of research and teaching revenues are then balanced. University 1 (the more reputable university) is more willing to set a quality standard that is high enough to dissuade university 2 (the less reputable university) from setting any $x_2 = x_1 + \varepsilon$. This is possible because university 1 can take advantage of its reputation to reinforce its position in the market and receiving the highest proportion of research funds. By doing this, the less reputable university is prevented from setting a higher quality standard than the most reputable university. If $t = 0$, the amount of teaching funds universities received per hired candidate r exactly compensates the fixed wage paid to candidates, w . Therefore, universities have no incentives to increase their sizes. As a result, (A.2) requires only a positive g to guarantee equilibrium existence. Second, we comment on the upper bound for g . This requirement ensures that the equilibrium solution is not a corner one where $x_1^* = x_2^* = 1$. Observe that, if g is high enough, particularly higher than $\bar{g}$,

then the optimal quality standard of university u , x_u depends on the level of x_v as follows: if x_v is low, then there is still room to compete for both research (by setting a high x_u) and teaching resources (by setting a low x_u such that $n_u > 0$). As x_v increases, university u increases x_u to receive both teaching and research resources. This process continues until x_v is sufficiently high. If it is the case, then during the next academic period, university u focuses only on research and no longer competes for teaching resources; thus, $n_u = 0$. Hence, the unique equilibrium candidate is such that both universities set the highest quality standard, $x_1^* = x_2^* = 1$, equally share research resources and hire no new faculty candidates for the next period, which does not seem a reasonable case. As such, there is no specialization in fund-seeking between universities as both mostly compete for the same type of funding.

Therefore observe that, by imposing (A.2) and as long as $g < \bar{g}$, there is fund-seeking specialization between universities: one competes mainly for research funds, and the other competes mainly for teaching funds. In other words, the research grant affects the degree of fund-seeking specialization in competing universities.¹² The intuition behind the fund-seeking specialization is as follows. Holding x_u fixed, it is observed from eqs [4] and [6] that a low differentiation in quality standards between universities (a slight reduction in x_v) implies greater losses in funds from teaching than in research funds for university v . Similarly, a great differentiation (a larger reduction in x_v) implies greater gains in funds from teaching than in research funds. Thus, as research grant g diminishes and universities' revenues depend more on teaching resources, they will manage to differentiate.

To obtain tractable analytical solutions, we impose that $\delta = 1$, which means that both human and physical capital have the same weight in the excellence production of universities, E_u , (see eq. [1]). We do not ignore that this assumption may lead to extreme solutions. Thus, we interpret our results as magnified tendencies. Nevertheless, we think that the qualitative results would not change dramatically for any $\delta < 1$.

Proposition 1 shows how the research grant determines the equilibrium quality standards (x_1^*, x_2^*) . In particular, it shows that the most reputable university sets the highest quality standard for the next period, that is, the most reputable university competes mainly for research resources and the less-

¹² Empirical work focused on the US suggests that the amount of research funds affects the universities' degree of specialization in terms of research intensity. In particular, the Research Universities Futures Consortium (2012) shows in a recent report that the scarcity of resources has caused a number of universities at the margins to no longer be able to bear the cost of supporting competitive research efforts, and as a result, their academic research activity will diminish.

reputable one competes mainly for teaching resources. We also find that there is a threshold for research grants g below which both universities set a quality standard below one. We denote this value by $\widehat{g}$, which stands for $\widehat{g}(a_1, a_2, t)$.

Proposition 1: *Suppose that (A.1) and (A.2) hold, and let $a_1 < a_2$ and $\delta = 1$. The research grant amount determines the equilibrium quality standards (x_1^*, x_2^*) as follows:*

- (i) *If $g > \widehat{g}$, then $x_2^* < x_1^* = 1$.*
- (ii) *If $g < \widehat{g}$, then $x_2^* < x_1^* < 1$.*

Proof: See the Appendix. ■

Proposition 1 shows that, as expected, the equilibrium quality standard set by each university increases with the research grant amount, g . This is because, as research funding increases, higher quality standards are better rewarded.¹³ Similarly, as research funding diminishes, then competition for research resources alone is no longer that worthwhile, and universities compete for both research and teaching resources. In this case, there are two possible equilibria. In both cases, university 1 takes advantage of its reputation and sets a quality standard higher than that of university 2. Observe that if x_v is low enough, then the situation is similar to that described above when g is higher than the upper bound $\bar{g}$. As x_v increases, all else being equal, p_u decreases, as do university u 's research resources and, thus, it needs to set a higher x_u to compensate for that reduction in p_u (because x_v is still low). As x_v increases further, university u needs to increase x_u as well. However, because g is not that high, university u needs to compete for teaching funds. Therefore, because an increase in x_u also implies a reduction in n_u , university u sets x_u just above x_v . Finally, if x_v is very high, university u decides to set $x_u < x_v$ to obtain teaching funds. Hence, we can conclude that if the research grant amount is sufficiently high ($g > \widehat{g}$), then university 1 can focus only on research and sets $x_1^* = 1$. However, if g is not high enough ($g < \widehat{g}$), then university 1 tries to obtain some teaching funds and sets $x_1^* < 1$; then, a unique equilibrium emerges where $x_2^* < x_1^* < 1$. Therefore, as commented above, there is certain degree of specialization in fund-seeking: university 1 competes mainly for research resources, whereas university 2 also competes for teaching funds.

We denote the excellence growth achieved in equilibrium by university u by E_u^* for $u \neq v$ and $u = 1, 2$, i. e., $E_u^* = E_u(x_u^*, x_v^*)$ for $E_u(x_u, x_v)$ in eq. [8] and $\delta = 1$. We

¹³ This relationship between the amount of research funds and universities' research performance is observed in some empirical studies. For example, Aston and Shutt (2009) study the UK case and find that the research quality (measured by the number of UKs share of world citations) has increased since the introduction of the Research Assessment Exercise (RAE) in 1986 (www.rae.ac.uk/Pubs/2004/01/rae0401.doc).

distinguish among two alternative scenarios that differ in the amount of funds devoted to financing research, g , that is, $g > \widehat{g}$ and $g < \widehat{g}$. Table 1 reports excellence growth in these scenarios:

Table 1: The excellence growth in equilibrium.

Funds \ Excellence	E_1^*	E_2^*
$g > \widehat{g}$	$\sqrt{(a_2 + t)g} - a_1$	$g + a_2 - 2(\sqrt{(a_2 + t)g} - t)$
$g < \widehat{g}$	$\frac{g}{2} - a_1 t + \left(\frac{a_2 + t}{a_1 + a_2 + 2t}\right)^2 g$	$\frac{(a_1 + t) + (a_2 + 2t)}{(a_1 + a_2 + 2t)^2} g$

Several comments can be made on Table 1. First, the increase in excellence obtained in equilibrium is higher for the more reputable university than for the less reputable one, regardless of the amount of funds because the more reputable university benefits from its reputation advantage. That is, $E_1^* > E_2^*$ for any g . Second, the equilibrium excellence growth achieved by each university is increasing in the amount of the research grant, g .

Finally, let E_c^* denote the equilibrium excellence growth obtained in the competitive setting. This could be interpreted as the sum of the amount of research and graduate students achieved by both universities for the next academic period:¹⁴

$$E_c^* = E_1^* + E_2^*, \quad [11]$$

where E_1^* and E_2^* are defined in Table 1; therefore, for $g > \widehat{g}$:

$$E_c^* = g - a_1 + a_2 + 2t - \sqrt{(a_2 + t)g}, \quad [12]$$

and for $g < \widehat{g}$ then:

$$E_c^* = t + \frac{((a_1 + t)^2 + (a_2 + t)^2 + t(a_2 + t))}{(a_1 + a_2 + 2t)^2} g. \quad [13]$$

It can be verified from eqs [12] and [13] that, as expected, the equilibrium excellence growth in the competitive setting is increasing with the research grant amount, g . Proposition 2 presents an important result of this study: namely, the impact of the heterogeneity or differential reputation between universities on the equilibrium excellence growth in competition E_c^* .

¹⁴ Observe that we are implicitly taking an utilitarian approach; thus, in our model, a social planner maximizing welfare in society maximizes the total amount of excellence for all universities operating in the market. This approach is in line with recent literature on the optimal organization of the university sector (see, for example, De Fraja and Valbonesi 2012).

Proposition 2: *The equilibrium excellence growth in competition E_c^* increases with the heterogeneity between competing universities.*

Proof: From eqs [12] and [13], it is easy to check that E_c^* is decreasing with a_1 and increasing with a_2 . ■

From Table 1, it can be verified that an increase in the heterogeneity between the competing universities increases the equilibrium excellence growth of university 1 and reduces the equilibrium excellence growth of university 2. Therefore, the final effect on the total increase in excellence in competition depends on which effect dominates. As Proposition 2 shows, the first effect is generally dominant. Recall that under (A.2), there is a certain degree of specialization because university 1 seeks mostly research funds, whereas university 2 also seeks teaching funds (see also Proposition 1). Therefore, an increase in heterogeneity affects both universities asymmetrically. First, it positively and strongly affects university 1 because it reduces its relative cost of acquiring research funds. Second, it negatively and weakly affects university 2 because it is competing mostly for teaching funds, for which the relative quality acquisition cost is not that significant, as commented above.

To conclude, based on Proposition 2, we find that the heterogeneity between competing universities modulates the extent to which the universities' fund-seeking specialization is exploited. Specifically, greater heterogeneity reinforces specialization benefits in terms of total excellence growth in competition.

3.2 Two Merged Universities

Responses to international competition can take a variety of forms, with special emphasis on institutional collaboration to strengthen research capacity, visibility and competitive position. Regarding mergers, the typical pattern is a combination between two or more institutions into a single regional or national entity that improves its global competitiveness.¹⁵ To resemble this situation, we now consider that there is only one university operating in the higher education market. We summarize the merging process by defining the quality acquisition

¹⁵ See the Introduction for several recent examples of mergers. An additional good illustration might be the recent case in France of the University of Provence-Aix Marseille I, the University of Mediterranean-Aix Marseille II and Paul Cezanne University-Aix Marseille II, University-Aix Marseille III, which merged and became the University Aix-Marseille. Another example is the Karlsruhe Institute of Technology (KIT) created under the Excellence Initiative program in Germany.

cost of the resulting institution as follows. Let this quality acquisition cost be denoted by a_m , where $a_m \in [a_1, a_2]$. This allows us to analyze several cases including the following two extreme ones: $a_m = a_2$ which means that the merger has a lower average reputation than competing universities, and $a_m = a_1$, which means that the merger has a higher average reputation than competing universities. The former case represents a situation in which the resulting university is perceived as being a copy of the least reputable university among the merged universities after the merging process. In contrast, the latter case captures a situation in which the most reputable university leads the merging process and imposes its reputation level on the resulting university. These are, of course, two extreme cases. As $a_m \in [a_1, a_2]$, the case where the merged institution has an initial reputation in between that of the two merging ones, is also considered. Finally, note that this assumption introduces economies of scale in the cost of acquiring quality, which shift the balance of excellence in favor of the merged university.¹⁶ Nevertheless, as we see below, we still find many cases where total excellence growth is larger in the competitive setting than in the merger one.

We analyze the university optimization problem, eq. [7], eq. [UP] in a context where there is only one university operating in the market and, thus, the competition for resources and faculty candidates vanishes. Let x_m denote the quality standard set by this merged university. Due to the absence of competition for new candidates with other universities, the number of new candidates hired by the merged university is $n_m(x_m) = 1 - x_m$. Observe that the lack of competition for research resources with other universities might lead to a situation where the merged institution does not have incentives to set a high quality standard. However, in order to give a more efficient use of research funds, and similarly to that in the competitive case, we consider a rule that allows allocating more funds the more quality demanding the institution is. Namely, we assume that the merged university obtains a proportion of the total research grant amount g that is equal to its quality standard, i. e., $p_m(x_m) = x_m$. As we see below, the funding agency fully allocates g in equilibrium. Recall from eq. [4] that, in the competitive case, unless both universities set the lowest quality standard (which is never the case in equilibrium), the funding agency also entirely allocates g . Therefore, as in equilibrium, the amount of research resources spent in the “merged” and “competing” settings coincide, then the comparison between both scenarios does not depend on the total available funds for research. It is important to highlight that we do not assume here that p_m is equal to 1. Observe that, in that case, the merged institution would have an incentive to

¹⁶ A large set of studies provides evidence on the presence of economies of scale for both public and private average-sized Higher Education Institutions in Anglo-Saxon and European countries (see the seminal paper by Cohn, Rhine, and Santos 1989 and references citing it).

hire all new candidates at the lowest feasible quality level, $x_m = 0$, thereby minimizing wage per candidate while still collecting all research funds.

From (A.1), and as $\delta = 1$, it is easy to verify that the excellence function of the merged university $E_m(x_m)$ is increasing with x_m . Hence, its optimal quality standard is $x_m^* = 1$. In other words, this implies that the merged university is so selective that it hires no new candidate for the next academic period. As mentioned above, if this is the case, then students would be taught by the already existing faculty members. As a result, the merged institution does not incur additional salary expenditure. Observe that this outcome is driven mainly by the linear specification of the excellence production function in eq. [1]. Hence, $E_m^* = g - a_m$. We interpret this outcome as a magnified tendency. Nevertheless, qualitative results would not change dramatically had we assumed $\delta < 1$ (see Footnote 7). It is interesting to highlight that, in this case, the equilibrium salary expenditure for this merged institution is equal to zero; thus, it is lower than or equal to that of competing universities. That is, although we did not model different salary schemes for the competing and merged settings, we obtain the standard result when comparing them, as mentioned above.

4 Competition versus Merger

We now compare total excellence growth in the competition E_c^* and merge E_m^* settings. In particular, we find that whether the merged institution produces a higher increase in excellence than competing universities depends on both the reputation costs of the competing and merged universities and the amount of research resources.

Let $\underline{a}$, which stands for $\underline{a}(a_1, a_m, t)$, denote a minimum threshold for the reputation of university 2 below which excellence growth in the merged setting is higher than that in the competitive setting, regardless of the amount of research resources available. Finally, let g^h and g_l , where $g_l < g^h$, and which stand for $g^h(a_1, a_2, a_m, t)$ and $g_l(a_1, a_2, a_m, t)$, respectively, denote two boundaries for the research resources above which merged universities produce a higher increase in excellence than competing ones and vice versa.

Proposition 3: *Suppose (A.1) and (A.2) hold, and let $\delta = 1$. Then, the following conditions hold:*

- (i) *If $a_m > 2a_1$, then $E_m^* > (<)E_c^*$ if and only if $g > (<)g^h$.*
- (ii) *If $a_m < 2a_1$, then the following two cases arise:*

- (ii.1) If $a_2 > \underline{a}$, then $E_m^* > (<) E_c^*$ if and only if $g > (<) g_l$.
(ii.2) If $a_2 < \underline{a}$, then $E_m^* > E_c^*$.

Proof. See the Appendix. ■

The intuition behind Proposition 3 is the following. The merger procedure has two effects on excellence growth. First, it diminishes the total salary expenditure due to the increase in market power and the reduced competition effect. Second, the cost of acquiring quality changes and depends on the resulting reputation, a_m . The final impact on excellence growth depends on which of the two effects dominates. As a_m increases, the loss in (average) reputation exceeds the gain in market power; then more resources are needed to produce a higher increase in excellence than in the competing setting. This is because the merged university sets the highest academic standard for the next period, whereas competing universities set higher quality standards as the amount of available research grant funding increases (see Proposition 1 above). If the reputation cost of the merged institution a_m is not that high, which we believe illustrates a more relevant situation, then the comparison between total excellence growth in both settings depends on both the amount of research grant resources and the reputation cost of university 2. In particular, we find that there is a boundary for the reputation cost of university 2 above which the excellence growth comparison in the two settings depends only on the amount of research resources available. In contrast, if the reputation cost of university 2 is below this boundary, then mergers guarantee the maximum increase in excellence regardless of the amount of research resources. Recall that for some fixed a_1 , a low (high) a_2 means a low (high) degree of heterogeneity. Therefore, the degree of heterogeneity between universities plays a crucial role in determining the type of market that guarantees the maximum increase in total excellence. The next proposition shows how the degree of heterogeneity between competing universities modulates the comparison of total excellence growth between competition and mergers.

Proposition 4: *The amount of research resources required for merged universities to achieve higher excellence growth than competitive universities increases with the heterogeneity between competing universities.*

Proof: See the Appendix. ■

Proposition 4 tells us that as the heterogeneity between the competing universities increases, the amount of resources needed for the merged institution to produce a

higher increase in excellence than the competing universities increases. The intuition could be as follows. If the two competing universities were to merge, as long as (A.2) holds, they would not take advantage of their potential synergy gains. Recall from (A.2) and Proposition 1 that, as long as g is not sufficiently high, then there is a certain degree of specialization between universities in terms of fund-seeking: university 1 is more specialized in seeking research funds, whereas university 2 is more specialized in seeking teaching funds. Therefore, a merger between universities does not guarantee maximum excellence growth. In addition, from Proposition 2, we know that greater heterogeneity between the universities reinforces these specialization benefits and increases their total increase in excellence in a competitive setting. As a result, as heterogeneity increases, a higher amount of research funds is required for an eventual merger process to guarantee higher excellence growth than competition.

5 Concluding Remarks

There is ample evidence (we name a few sources in the paper) that reshaping the higher education sector to compete in the global market for prestige or excellence is a priority of national governments in several countries. As a result, universities around the world are currently being encouraged to form “strategic alliances” that make them more visible and reputable internationally, allowing them to better compete for talent. Surprisingly, it is difficult to find theoretical research regarding mergers between higher education institutions. In this paper, we analyze whether such mergers are optimal in terms of excellence growth. A very simple model is considered. Nonetheless, the model is able to generate clear policy guidelines for mergers between universities. We find that, under certain assumptions, the relationship between the initial reputations of universities and the amount of research funds available plays a key role in determining the success or failure of mergers. First, the amount of research resources affects the degree of fund-seeking specialization between competing universities. Second, the degree of heterogeneity between them (measured by their differential reputation) modulates the extent to which the specialization is exploited. In particular, greater heterogeneity reinforces specialization benefits in terms of the total increase in excellence. Therefore, we find that as the heterogeneity between competitors increases, the amount of funds needed to make a merger profitable in terms of excellence growth increases.

The paper abstracts from the design of an optimal funding policy, which has previously been considered by Gautier and Wauthy (2007) and De Fraja (2011),

among others.¹⁷ Abstracting from this concern enables us to isolate the role of the amount of research funds and the degree of heterogeneity between universities in the success or failure of mergers, which has not been considered in the prior literature. Indeed, this is a major contribution of this paper.

Future research should proceed by extending both the theoretical framework and the empirical testing of its predictions. We consider that studying the case of a duopoly to monopoly is sufficient to illustrate our main results in a simple way. These results can be generalized in a richer model that will be a fruitful area of research. We have taken a relatively conservative approach regarding the channels through which mergers enhance the excellence of universities. In particular, we have considered only their effects on national higher education markets. On one hand, this assumption allows for an intuitive discussion of the comparison between mergers and competition. On the other hand, this assumption is based on empirical facts regarding the proportion of both research funds and academics coming from abroad (see the Introduction). Nevertheless, it could be interesting to consider the effects of mergers on international markets. This could be analyzed by extending our model and considering two countries and two universities where each can either compete or merge. We assume that universities maximize their prestige or excellence. Nevertheless, the debate on the appropriate university objective has not been settled. For instance, as we noted above, the objective of universities could also consist of maximizing rents. We could consider the behavior of the bureaucrats (or deans) who manage universities as an alternative rationale for universities being rent-maximizers. The main idea is that these managers are unable to correctly understand the meaning of the public interest. As a result, they may act to satisfy personal interests, for example, through higher budgets, which allows for the hiring of more bureaucrats. Interestingly, in our analysis, both approaches – maximizing excellence and rents – are equivalent under two mild conditions, particularly as long as $\delta = 1$ and the salary scheme includes only the fixed wages for faculty candidates, w . In addition, we are aware that the objective of universities and that of the government may not always coincide. However, in this paper, we do not consider this alternative, as our focus is on the effects of mergers on excellence.¹⁸ An additional extension might

¹⁷ Gautier and Wauthy (2007) analyze the optimal allocation of funds among departments. More recently, De Fraja (2011) studies the optimal funding for scientific research when the funding agency distributes funds among research institutions and allocates them between basic and applied research.

¹⁸ See Gary-Bobo and Trannoy (2008), who first disassociate the government and the universities by modeling a principal-agent relationship between them, and De Fraja (2011) for a more recent contribution.

consist of studying this possibility. Finally, our theoretical results yield two hypotheses that need to be tested empirically: the impact of the differences between the ex ante reputations of universities and the role of the amount of research resources in the success of an eventual merging process.

To conclude, we believe that the results presented here are relevant to several recent debates in the literature on university governance. This is especially true in Europe, where the European Commission (2008) identifies a tendency of uniformity and egalitarianism in many national higher education systems and little emphasis on world-class excellence. In this context, certain governments are designing incentives for joint proposals among different universities. To the extent that these initiatives are used as means to promote excellence, a better understanding of the impacts of mergers in the higher education sector would allow policy makers to assess the efficacy of their use and develop strategies to overcome unexpected consequences. In particular, our results provide support for policies that promote greater competition among universities whenever the heterogeneity between them is sufficiently high and the amount of available resources is not very large.

Acknowledgments: An earlier version of this paper circulated under the title “The expansion of the higher education sector: A tale of two regions”. We are grateful for the comments and suggestions by Elena Del Rey, Iñigo Iturbe-Ormaetxe, Julien Jacqmin, Moshe Justman, Darío Maldonado, Francisco Martínez-Mora, Joel Sandonis and Alain Trannoy. We would like to thank seminar participants at Málaga, VI Workshop on Public Policy Design in Girona, the 11th Journées Louis-André Gérard-Varet and the 2013 European Public Choice Society Meeting. Finally, Marisa Hidalgo thanks CREST (ENSAE), where part of this research was carried out, for their hospitality. Financial support from the Spanish Ministry of Innovation and Science [ECO2014-53767P, ECO2014-57413], Instituto Valenciano de Investigaciones Económicas and Junta de Andalucía [SEJ-5980; SEJ-426] is gratefully acknowledged.

Appendix

Proof of Proposition 1: We first derive the best reply functions for both universities denoted by $b_u(x_v)$. From (A.1) and eqs [4] to [7] we can check that $E_u(x_u, x_v)$ is concave in each of the different intervals. In particular, we have that $\lim_{x_u \rightarrow 0} \frac{\partial E_u}{\partial x_u} |_{x_u < x_v} > 0$. Note that $\lim_{x_u \rightarrow 1} \frac{\partial E_u}{\partial x_u} |_{x_u > x_v} < 0$ if either $x_v < \hat{x}_v(a_u, g, t)$, where

$\widehat{x}_v(a_u, g, t)$ is such that $\frac{(1+\widehat{x}_v)^2}{\widehat{x}_v} = \frac{g}{a_u+t}$, or $g < 4(a_u+t)$. The sign of $\lim_{x_u \rightarrow x_v} \frac{\partial E_u}{\partial x_u} \big|_{x_u < x_v}$ and $\lim_{x_u \rightarrow x_v} \frac{\partial E_u}{\partial x_u} \big|_{x_u > x_v}$ also depends on the value of x_v . In particular, $\lim_{x_u \rightarrow x_v} \frac{\partial E_u}{\partial x_u} \big|_{x_u < x_v} = \lim_{x_u \rightarrow x_v} \frac{\partial E_u}{\partial x_u} \big|_{x_u > x_v} > 0$ if and only if $x_v < \frac{g}{4(a_u+t)}$. Consider two cases: (a) $g < 4(a_u+t)$ which implies that $\lim_{x_u \rightarrow x_v} \frac{\partial E_u}{\partial x_u} \big|_{x_u > x_v} < 0$. If $x_v < \frac{g}{4(a_u+t)}$, then $\lim_{x_u \rightarrow x_v} \frac{\partial E_u}{\partial x_u} \big|_{x_u < x_v} = \lim_{x_u \rightarrow x_v} \frac{\partial E_u}{\partial x_u} \big|_{x_u > x_v} > 0$ and thus, from eqs [4] to [6], the best reply of university u is $b_u(x_v) = -x_v + \sqrt{x_v \frac{g}{(a_u+t)}}$ which is higher than x_v . If $x_v > \frac{g}{4(a_u+t)}$, then $\lim_{x_u \rightarrow x_v} \frac{\partial E_u}{\partial x_u} \big|_{x_u < x_v} = \lim_{x_u \rightarrow x_v} \frac{\partial E_u}{\partial x_u} \big|_{x_u > x_v} < 0$ and thus, from eqs [4] to [6], we have that the best reply of university u depends on the value of x_v . In particular, if $x_v < \widetilde{x}_v(a_u, g, t)$, where $\widetilde{x}_v(a_u, g, t)$ is such that $E_u(-\widetilde{x}_v + \sqrt{\widetilde{x}_v \frac{g}{(a_u+t)}} | \widetilde{x}_v) \big|_{x_u < x_v} = \lim_{x_u \rightarrow x_v} E_u(x_u, \widetilde{x}_v) \big|_{x_u > x_v}$, then $b_u(x_v) = x_v + \varepsilon$ and if $x_v > \widetilde{x}_v(a_u, g, t)$ then $b_u(x_v) = -x_v + \sqrt{x_v \frac{g}{(a_u+t)}}$ which now is lower than x_v . To sum up, if $g < 4(a_u+t)$ then the best reply of university u is:

$$b_u(x_v) = \begin{cases} -x_v + \sqrt{x_v \frac{g}{(a_u+t)}} & \text{if } x_v < \frac{g}{4(a_u+t)} \\ x_v + \varepsilon & \text{if } \frac{g}{4(a_u+t)} \leq x_v < \widetilde{x}_v(a_u, g, t) \\ -x_v + \sqrt{x_v \frac{g}{(a_u+t)}} & \text{if } x_v \geq \widetilde{x}_v(a_u, g, t). \end{cases} \quad [14]$$

(b) $g > 4(a_u+t)$. If $x_v < \widehat{x}_v$, then $\lim_{x_u \rightarrow 1} \frac{\partial E_u}{\partial x_u} \big|_{x_u > x_v} < 0$ and thus, from eqs [4] to [7], we have that the best reply of university u is $b_u(x_v) = -x_v + \sqrt{x_v \frac{g}{(a_u+t)}}$ which is higher than x_v . If $x_v \geq \widehat{x}_v$, then $\lim_{x_u \rightarrow 1} \frac{\partial E_u}{\partial x_u} \big|_{x_u > x_v} \geq 0$ and thus, from eqs [4] to [6], the best reply of university u is $b_u(x_v) = 1$. Thus, if $g > 4(a_u+t)$, then the best reply of university u for any x_v is:

$$b_u(x_v) = \begin{cases} -x_v + \sqrt{x_v \frac{g}{(a_u+t)}} & \text{if } x_v < \widehat{x}_v(a_u, g, t) \\ 1 & \text{if } x_v \geq \widehat{x}_v(a_u, g, t). \end{cases} \quad [15]$$

Figure 1 depicts the best reply function of university u for $u=1$.

Next, we combine these best reply functions to get the Nash equilibrium.

(i) Let $g > \widehat{g}$ where $\widehat{g} = \frac{(a_1+a_2+2t)^2}{a_2+t}$. Then we can distinguish two cases: a) If $g > \overline{g} = 4(a_2+t)$ then, from eq. [15] and for $u=1,2$ the unique equilibrium is $x_1^* = x_2^* = 1$. However, from (A.2) we rule out this case. b) If $g < 4(a_2+t)$ and then, from eq. [15] for university 1 and eq. [14] for university 2, we can check

Figure 1: Best reply function and equilibrium outcomes.

that an equilibrium will always exist if $b_2(x_1 = 1) > \hat{x}_2$ which holds if and only if $g > \hat{g}$. This equilibrium is $x_1^* = 1$ and $x_2^* = -1 + \sqrt{\frac{g}{a_2 + t}}$. (ii) And finally, let $g < \hat{g}$ and now we can distinguish two cases: a) If $g > 4(a_1 + t)$ then an equilibrium exists if the following two conditions holds: (a.1) $b_2(x_1 = 1) < \hat{x}_2$, which holds if and only if $g < \hat{g}$ and (a.2) $\tilde{x}_1(a_2, g, t) < x_1^*$, which holds if and only if $g > \underline{g}(a_1, a_2)$ and thus from (A.2) this condition holds. (b) If $g < 4(a_1 + t)$ then an equilibrium exists if the following two conditions holds: (b.1) $b_1(x_2 = \frac{g}{4(a_1 + t)}) > \tilde{x}_1$ and (b.2) $\tilde{x}_1(a_2, g, t) < x_1^*$. However, it can be checked that $b_1(x_2 = \frac{g}{4(a_1 + t)}) > x_1^*$ for any a_1, a_2 and g . Thus, (b.2) is a sufficient condition to ensure the existence of equilibrium in this case. Thus, from (A.2), this equilibrium always exists. The equilibrium is $x_u^* = \frac{a_v + t}{(a_v + a_u + 2t)^2} g$ for $u = 1, 2$, i.e., $x_2^* < x_1^* < 1$. Figure 1 also presents the resulting equilibrium outcomes. ■

Proof of Proposition 3: First, from eq. [12], we define $g^h > \widehat{g}$ as the level of g that satisfies $E_c^*(a_1, a_2, g^h, t) = E_m^*(g^h, a_m)$, i.e., $g^h = \frac{(a_2 - a_1 + a_m + 2t)^2}{(a_2 + t)}$. Similarly, from eq. [13], $g_l \leq \widehat{g}$ is defined to be such that $E_c^*(a_1, a_2, g_l, t) = E_m^*(g_l, a_m)$ i.e. $g_l = \frac{(a_m + t)(a_2 + a_1 + 2t)^2}{(2a_1 + t)(a_2 + t)}$. Finally, $\underline{a}$ is such that $a_2 \leq (\geq) \underline{a}$ if and only if $g_l \leq (\geq) \widehat{g}$.

(i) Let $a_m > 2a_1$. First, if $g > \widehat{g}$ then from eq. [12] and the definition of g^h it can be checked that $E_m^* > E_c^*$ if and only if $g > g^h$. Second, if $g < \widehat{g}$ then from eq. [13] and the definition of g_l it can be checked that as $g_l > \widehat{g}$ then $E_m^* < E_c^*$ always holds.

(ii) Let $a_m < 2a_1$ and then we distinguish two cases depending on the reputation cost of university 2: (ii.1) Let $a_2 < \underline{a}$. Then, from Table 1 and the definition of $\underline{a}$ we have that $E_m^* > E_c^*$ always holds for any g . (ii.2) Let $a_2 > \underline{a}$ and first, if $g > \widehat{g}$ then from eq. [12] and the definition of g^h it can be checked that as $g^h < \widehat{g}$ then $E_m^* > E_c^*$. And second, if $g < \widehat{g}$ then from eq. [13] and the definition of g_l and $\underline{a}$ it can be checked that $E_m^* > E_c^*$ if and only if $g > g_l$. ■

Proof of Proposition 4: First, if $a_m > 2a_1$ then from the definition of $g^h(a_1, a_2, a_m, t)$ in Proposition 3 it can be checked that this boundary is increasing with a_2 and decreasing with a_1 . Second, if $a_m < 2a_1$ and $a_2 < \underline{a}$ then from (A.2) $E_m^* > E_c^*$ for any g . As a_2 increases (which, for some fixed a_1 represents an increase in the heterogeneity) then eventually $a_2 > \underline{a}$. In this case $E_m^* > E_c^*$ if and only if $g > g_l(a_1, a_2, a_m, t)$. In addition, from the definition of $g_l(a_1, a_2, a_m, t)$ it can be checked that this boundary is increasing with a_2 and decreasing with a_1 . ■

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