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University Competition and Transnational Education: The Choice of Branch Campus

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University Competition and Transnational Education: The Choice of Branch Campus*

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Abstract

We present a theoretical framework in which an elitist and a non-elitist university in a developed country compete by choosing their admission standards and deciding whether or not to open a branch campus in a developing country. Students from a developing country attend university either if a branch campus is opened or if they can afford to move to the developed country. We characterise the equilibria by focussing on the relationship between the investment costs of a branch campus and the graduate wage. There are three type of equilibria: (i) no branch campus, (ii) only the elitist university opens a branch campus and (iii) both universities engage in transnational education, opening a branch campus. Very high investment costs discourage the opening of a branch campus. A rise in the graduate wage increases the incentive for opening a branch campus, although this

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incentive is stronger for the elitist than the non-elitist university. Surprisingly, a government subsidy for opening a branch campus may be ineffective in increasing university attendance.

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Keywords: University competition, branch campus, admission standards, transnational education.

1 Introduction

A rapidly growing number of universities across the world are engaging in transnational education activities by establishing branch campuses in other countries. Transnational education is defined as arrangements in which courses or degree programmes offered by an institution in one country are delivered to students located in a different country [Ziguras (2003)].

The evidence shows that the international branch campus market has become more competitive. Higher education institutions from 22 countries have established branch campuses abroad compared with 17 countries in 2006. Most of these campuses (111 out of 162) were established by institutions in the Anglophone nations, the US continuing to overshadow all others with its 78 offshore bases accounting for 48% of the total. The US is followed by Australia with 14 campuses, 9% of the total number, the UK with 13 or 8% of the total, and France and India each with 11. Several other countries, including Mexico with seven small campuses, the Netherlands with five, Malaysia with four and Canada and Ireland with three each, operate multiple branches abroad. Since 2006, institutions from five new source countries have established at least one overseas campus: these are Lebanon, Malaysia, South Korea, Sri Lanka and Switzerland [Becker (2009)].

In the higher education economics literature, contributions on the effects of branch campuses are scarce, with few but notable exceptions. Lien (2006) analyses a university market in a developing country, with a domestic university and the branch campus of a foreign university. The domestic university provides education in both global knowledge (commonly accepted and being helpful for developing countries probably in the future) and local knowledge (being directly helpful for developing countries), whereas the branch campus specializes in global knowledge education only. Students have different learning ability in global knowledge (but not in local knowledge) and they choose which university to attend based upon the expected wages. If graduates from the branch campus have opportunities to work abroad and earn higher incomes, then an increase in the wage in the foreign country will lead to a reduction in local knowledge production. Lien (2008) extends Lien (2006) by considering different qualities of the branch campus. Finally, Lien and Wang (2010) examine student decisions in a developing country about whether to attend the local university or study abroad. All these papers focus on the effects of a branch campus on the question of brain drain on the developing country and treat the decision to open a branch campus as exogenous and not determined in equilibrium. Further, there is no university competition, in the sense that universities do not act strategically. The growing importance of transnational education activities, such as the establishment of branch campuses, and its role in competition among universities appears not to have been investigated thoroughly in the literature. This is the main objective of the present paper. Moreover, it is also important to determine how university competition interacts with policy interventions aiming to favour the openings of branch campuses. The paper is also related to the literature on spatial competition among universities [Del Rey (2001), De Fraja and Iossa (2002)]. In particular, the modelling framework borrows some elements from the analysis of university competition of De Fraja and Iossa (2002)[1].

To the best of our knowledge, this is the first paper to analyse the deci-

[1] In their model, the two universities are located in different towns and compete by setting admission standards only. They show that universities choose the same admission standard only when the mobility cost (i.e., the cost for a student to attend university away from her town) is high; when the mobility cost is very low, there is no pure strategy equilibrium, whereas asymmetric equilibria exist for intermediate values of the mobility cost. Compared to De Fraja and Iossa (2002), in the present paper universities are located in the same country, and have the option of opening a branch campus overseas. Also, we assume that one university always sets its standard higher than the competitor. In other words, we focus on asymmetric cases, by excluding the case in which both universities set the same standard

sion of investing in a branch campus within a competitive environment. In a simple stylised model, two universities operating in a developed country compete by choosing their admission standards and deciding whether or not to open a branch campus in a developing country. One of the two universities is "elitist", in the sense that it keeps its admission standard always higher than its competitor. Thus, the location of universities along the admission standard spectrum is exogenous. A student who is admitted to university will graduate with certainty and will obtain a higher income in the job market. Students from a developing country can attend university either if a branch campus is opened or if they are "privileged", i.e., if they can borrow money (from the family or the financial sector) to move to the developed country. So students decisions' depend on travel costs and their borrowing constraints while university decisions depend on the fixed investment costs of opening the branch campus and their revenues.

We investigate the relationship between investment costs and graduate wages. Very high investment costs discourage the opening of a branch campus. An increase in the graduate wage increases the incentive for opening a branch campus, although the incentive is stronger for the elitist than the non-elitist university. This is due to the fact that students prefer to attend the elitist university, so that the demand for higher education is filled from the elitist university and the non-elitist university covers the remainder. Therefore three possible equilibria emerge: (i) no branch campus is established, (ii) one branch campus is opened by the elitist university only and (iii) each university opens a branch campus. Surprisingly, an increase in the proportion of privileged students increases the chance of an equilibrium of type (ii) to the detriment of equilibrium (i). The intuition is the following: an increase in privileged students reduces the demand for university from students who stay in the developing country. The non-elitist university suffers from the fall in the demand relatively more than the elitist university, given the higher benefit from the latter from opening a branch campus. We also consider the role of the government in the developing country in offering subsidies towards the opening of branch campuses with the aim of increasing university attendance. We find that government subsidies to favour branch campuses might in fact prevent the opening of them. This surprising result can be explained as follows. Since the elitist university gains more than the non-elitist university, the subsidy favours relatively more the latter than the former. Thus the elitist university has a relatively lower incentive in opening a branch campus, compared to its competitor, than in the case with no subsidy. This in turn may negatively affect the incentive of the non-elitist university.

The remainder of the paper is organised as follows. Section 2 presents the modelling framework and Section 3 provides the equilibrium analysis. Section 4 presents an example and section 5 introduces government intervention in the form of a subsidy. Section 6 provides some brief concluding remarks.

2 The model

Consider a large population of potential students that is evenly distributed in two countries, 1 and 2. In each country the number of students is normalised to one. Country 1 can be thought of as a "developed" country. In Country 1 two universities, denoted by A and B, are established. Country 2 can be thought as a "developing" country, and we assume that there are no local universities.[2] However, university A and B may decide to open a branch campus (from now on, BC) in Country 2.

[2] This is a simplifying assumption in order to make the analysis more compact and tractable. The focus of the paper is on the choice of opening up a branch campus by the foreign universities. In the present work, local universities do not engage in transnational activities in a reciprocal manner.

2.1 Universities

Following De Fraja and Iossa (2002), each university i, $i = A, B$, cares about its "prestige" consisting of the following parts:

(i) the number of enrolling students n_i, where

$$n_i = \begin{cases} n_{i1} + n_{i2} & \text{if a BC is opened} \\ n_{i1} & \text{if no BC is opened} \end{cases}$$

(ii) the quality of the student body Θ (i.e., average ability), and

(iii) the expenditure on research R_i.

Hence the objective function of a university is written as:

$$W(n_i, R_i, \Theta) - \Phi_i, \tag{1}$$

where W is the benefit associated to "prestige", while

$$\Phi_i = \begin{cases} F & \text{if a BC is opened} \\ 0 & \text{if no BC is opened} \end{cases}$$

are the fixed costs associated with opening a branch campus. The first partial derivatives of W in (1) are all positive, and $W_{nn}(\cdot), W_{RR}(\cdot), W_{\Theta\Theta}(\cdot) < 0$. Each university has a budget determined by the amount of tuition fees collected by the enrolled students, fn_i, where $f > 0$ is the fees per student. Tuition fees f are set by the government agency in charge of the higher education system: universities are not free to choose what students are charged in fees.[3] Therefore, each university:

[3] This simplifying assumption can be justified as a reasonable approximation of current practice in many European countries and beyond but also because it allows us to analyse the decisions on transnational investment in isolation from decisions about raising revenues.

1. chooses the required standard necessary to admit a student in each campus. We denote this by $x_{ij} \in \left[\underline{x}_{ij}, 1\right], i = A, B,\ j = 1, 2$, where $\underline{x}_{ij} > 0$ is the lowest possible admission standard. This implies that only students who reach at least standard x_{ij} are accepted at institution i with campus in Country j;

2. decides whether or not to open a BC in Country 2 at a fixed cost $F > 0$.

Further, suppose that teaching n_i students carries a cost of

$$C(n_i) = \begin{cases} c(n_1) + c(n_2) & \text{if a BC is opened} \\ c(n_1) & \text{if no BC is opened} \end{cases},$$

with $c'(n_j) > 0$, $c''(n_j) > 0$, $j \in \{1, 2\}$. Thus the teaching cost is considered separately for each university site. This assumption aims to represent better a university technology in the real world: the costs are increasing and convex within each campus, due to the number of staff, classroom size, equipment, laboratories, and so on.

Finally, we assume that university A always sets a higher standard than university B.

Assumption 1 $x_{Aj} > x_{Bj}$.

By doing this, we impose the existence of an "elitist" university (university A) that always sets a higher admission standard than the competitor. The underlying justification is that, in the real world, some universities have higher prestige than others and, given the same admission standard and assuming no limits in university places, all students would choose to attend the elitist university.

2.2 Students

Students differ in ability, denoted by $\theta \in [0, 1]$. In each country, students' distribution by ability is $G(\theta)$, with $G(0) = 0$, $G(1) = 1$ and density $g(\theta) =$

$G_\theta(\theta)$. The admission standard set by a university, x_{ij}, is in the same support as ability, so that $x_{ij} \in [0,1]$ and $x_{ij} = \theta_{ij}$ where θ_{ij} is the lowest ability student that can be accepted by university i in Country j.[4] If a student attends university, she graduates with certainty at the end of the university period. Still with certainty, in the labour market she will receive a wage surplus for being a graduate ("graduate wage") $U(x_{ij})$, depending on the university admission threshold x_{ij}. A student objective function is:

$$U(x_{ij}) - f - T,$$

where $U_{x_{ij}}(x_{ij}) > 0$ and

$$T = \begin{cases} t & \text{if a student moves to attend university} \\ 0 & \text{if a student does not move} \end{cases},$$

T representing mobility costs (flight tickets, rents, and the like). For the sake of simplicity, we assume $U\left(\underline{x}_{ij}\right) > f$. In other words, the lowest possible graduate wage is higher than tuition fees. This ensures that every student is willing to attend university irrespective of f. A possible interpretation is that the government agency designs tuition fees in order to give incentives to the largest number of students to attend university. This assumption simplifies the analysis as f does not play any role in determining the demand function of students, but only determines a university's budget.

To simplify the analysis, all students from Country 1 attend university

[4] The results do not change by assuming that admission standards may change according to a student's origins. In equilibrium, universities would set the same standards to students coming from different countries. Our results may be interpreted as follows. Usually, a university admits foreign students by asking further requirements than a local student. An example can be a standardized test, or a language test. However, the extra requirement compensates for the lack of information about the education system of the student's country of origins.

in Country 1, even if at least one BC is present in Country 2.[5] On the other hand, in Country 2 there is an exogenous number of students $\beta \in (0,1)$, denoted as "privileged" who can borrow, either from their family or the banking system, the amount of money to cover the mobility costs t. β is independent of a student's level of ability.

A student who does not attend university has a reservation utility of $U(0) < U(x_{ij})$, for all $x_{ij} \in \left[\underline{x}_{ij}, 1\right]$, so that a student from the developed country would surely attend university if admitted. A student from the developing country would surely attend university if admitted and either

- there is a BC, or
- there is no BC but she belongs to the group of privileged students and $U(x_{ij}) - f \geq t$.

Conversely for $U(x_{ij}) - f < t$, a student from Country 2 attends university only if a BC is present. Notice that, if $U(x_{ij}) - f \geq t$ and only University B opened a branch campus, then a student from Country 2 who can be admitted to University A would move to Country 1 only if (i) she is privileged and (ii) $U(x_{A1}) - t \geq U(x_{B2})$. In other words, a student may be better off attending the BC of the non-elitist university if the cost of moving abroad is too high, since the increased benefit from attending the elitist university is more than offset by the moving costs.

The next definition is convenient.

Definition 1 *Let t^* denote the cost of moving to Country 1 such that*

$$U(x_{A1}) - t^* = U(x_{B2}).$$

[5] This is because we focus purely on the decision of a university's transnational investment in a BC.

3 Equilibria

3.1 Students' admission

The following propositions follow directly from $U'(x_{ij}) > 0$ and the discussion in the preceding section. The first proposition establishes university attendance of students from Country 1.

Proposition 1 *Consider students living in Country 1. University $i \in \{A, B\}$ sets standard x_{i1}, and by assumption 1, $x_{A1} > x_{B1}$.*

1. *Let student with ability θ_{A1} attend university A. Then all students with ability $\theta > \theta_{A1}$ also attend university A.*

2. *Let student with ability θ_{B1} attend university B. Then all students with ability $\theta_{B1} < \theta < \theta_{A1}$ also attend university B.*

This follows from the fact that a student with higher ability gains more from attendance at a university with a stricter admission test (Epple and Romano (1998), and De Fraja and Iossa (2002)). An immediate consequence of Proposition 1 and the characterization of a student's ability is the following.

Corollary 1 *Consider students living in Country 1. Let university $i \in \{A, B\}$ set standard x_{i1}, and Assumption 1 holds. A student attends University A if $\theta \in [x_{A1}, 1]$ and University B if $\theta \in [x_{B1}, x_{A1})$.*

The next proposition establishes university attendance of students from Country 2. For these students, university attendance depends on (i) whether or not one or two branch campus are opened, and (ii), in the case where only University B opens a branch campus, whether t is greater or not than t^*. Indeed, a student with high ability may be admitted to University A, but the mobility costs are high so that the student may prefer to attend the branch campus of University B.

Proposition 2 *Consider students living in Country 2. Let university $i \in \{A, B\}$ set standard x_{ij} for their site in Country j with $x_{Aj} > x_{Bj}$ (assumption 1).*

1. ***No BC:***

   (a) *Let a privileged student with ability θ_{A1} attend university A. Then β students with ability $\theta > \theta_{A1}$ also attend university A.*

   (b) *Let a privileged student with ability θ_{B1} attend university B. Then β students with ability $\theta_{B1} < \theta < \theta_{A1}$ also attend university B.*

2. ***University** A **operates BC:***

   (a) *Let a student with ability θ_{A2} attend university A. Then all students with ability $\theta > \theta_{A2}$ also attend university A.*

   (b) *Let a privileged student with ability θ_{B1} attend university B. Then β students with ability $\theta_{B1} < \theta < \theta_{A1}$ also attend university B.*

3. ***University** A **and** B **operate BC:***

   (a) *Let a student with ability θ_{A2} attend university A. Then all students with ability $\theta > \theta_{A2}$ also attend university A.*

   (b) *Let a student with ability θ_{B2} attend university B. Then all students with ability $\theta_{B2} < \theta < \theta_{A2}$ also attend university B.*

4. ***University** B **operates BC, and** $t \leq t^*$ **(Case 1):***

   (a) *Let a privileged student with ability θ_{A1} attend university A. Then β students with ability $\theta > \theta_{A1}$ also attend university A.*

   (b) *Let a student with ability θ_{B2} attend university B. Then all students with ability $\theta_{B2} < \theta < \theta_{A1}$ and $1 - \beta$ students with ability $\theta > \theta_{A1}$ also attend university B.*

5. ***University* B *operates BC, and* $t > t^*$ *(Case 2):***

   (a) *No students from Country 2 attend university A.*

   (b) *Let a student with ability θ_{B2} attend university B. Then all students with ability $\theta > \theta_{B2}$ also attend university B.*

Notice that, in the case in which University B is the only university to open a BC and $t \leq t^*$ (case 4), students with ability at least θ_{A1} attend University A only if they are privileged. If they are not, they will attend the BC of University B. Conversely, in the case in which University B operates a BC only and $t > t^*$, then none of the students of ability at least θ_{A1} from Country 2 will attend University A, since the increase in utility from attending University A is more than offset by the moving costs. The equivalent of Corollary 1 for students of Country 2 follows.

Corollary 2 *Consider students living in Country 2. Let university $i \in \{A, B\}$ set standard x_{ij} in their site in Country j with $x_{Aj} > x_{Bj}$ (assumption 1).*

(i) ***No BC:*** *a student attends University if she is privileged. In particular, University A if $\theta \in [x_{A1}, 1]$ and University B if $\theta \in [x_{B1}, x_{A1})$.*

(ii) ***University* A *operates BC:*** *a student attends University A if $\theta \in [x_{A2}, 1]$ and University B if privileged and $\theta \in [x_{B1}, x_{A1})$.*

(iii) ***University* A *and* B *operate BC:*** *a student attends University A if $\theta \in [x_{A2}, 1]$ and University B if $\theta \in [x_{B2}, x_{A2})$.*

(iv) ***University* B *operates BC, and* $t \leq t^*$*:*** *a student attends University A if privileged and $\theta \in [x_{A1}, 1]$ and University B either if non-privileged and $\theta \in [x_{A1}, 1]$ or, if not privileged and $\theta \in [x_{B2}, x_{A1})$.*

(v) ***University* B *operates BC, and* $t > t^*$*:*** *a student never attends University A, and attends University B if $\theta \in [x_{B2}, 1]$.*

Propositions 1 and 2 allow us to simplify the interaction between universities and students. Indeed, we can set up a two-stage, two-agent game with universities A and B as the players. In the first stage, the strategy space is binary, and consists of the decision of whether to open (or not) a branch campus in country 2. In the second stage, the strategy space is given by the admission standard, $x_A \in X$ and $x_B \in X$. The equilibrium concept is subgame perfect equilibrium by backward induction. Figure 1 depicts the timing of the game.

Figure 1. The timing of the game

Stage 1		**Stage 2**
Universities decide whether to open a BC	$\rightarrow$	Universities set their admission standard

3.2 Admission standards

In the second stage, universities set their admission standard in order to maximise their payoff function, which is given by:

$$\pi_i = W\left(n_i\left(x_{Aj}, x_{Bj}\right), fn_i\left(x_{Aj}, x_{Bj}\right) - c\left(n_i\left(x_{Aj}, x_{Bj}\right)\right), \Theta\left(x_{Aj}, x_{Bj}\right)\right) - \Phi_i,$$

where $n_i\left(x_{Aj}, x_{Bj}\right)$ and $\Theta_i\left(x_{Aj}, x_{Bj}\right)$ are the number of students admitted and the average quality of students at University i, $i = A, B$, respectively, given the admission standards $\left(x_{Aj}, x_{Bj}\right)$ for all $j = 1, 2$. Notice that $R = fn_i\left(x_{Aj}, x_{Bj}\right) - c\left(n_i\left(x_{Aj}, x_{Bj}\right)\right)$, where R is the university budget. Also, it is clear that $\partial\Theta_i / \partial x_{ij} > 0$: an increase in a university's admission standard increases the average ability of that university's students. Of course the number of admitted students will also depend on a university's decision about opening a BC. In particular, according to Corollary 1 and 2, the number of admitted student at University A is given by

$$n_A = \begin{cases} (1+\beta)(1-G(x_{A1})) & \text{no BC} \\ (1-G(x_{A1})) + (1-G(x_{A2})) & \text{A BC} \\ \sum_j^{1,2} (1-G(x_{Aj})) & \text{A and B, BC} \\ (1+\beta)(1-G(x_{Aj})) & \text{B BC, A no BC and } t \le t^* \\ (1-G(x_{Aj})) & \text{B BC, A no BC and } t > t^* \end{cases},$$

whereas the number of admitted students at University B is given by:

$$n_B = \begin{cases} (1+\beta)(G(x_{A1}) - G(x_{B1})) & \text{no BC} \\ (G(x_{A1}) - G(x_{B1})) + \beta(G(x_{A12}) - G(x_{B1})) & \text{A BC} \\ \sum_j^{1,2} (G(x_{Aj}) - G(x_{Bj})) & \text{A and B, BC} \\ (1+\beta)(G(x_{A1}) - G(x_{B1})) + (1-\beta)(1-G(x_{B2})) & \text{B BC, A no BC and } t \le t^* \\ (G(x_{A1}) - G(x_{B1})) + (1-G(x_{B2})) & \text{B BC, A no BC and } t > t^* \end{cases}.$$

Thus a university's problem in the second stage is given by

$$\max_{x_{ij}} W(n_i(x_{ij}), fn_i - c(n_i(x_{ij})), \Theta_i(x_{ij})) - \Phi_i,$$

where $j = 1$ if a university does not open a BC and $j = 1, 2$, if a BC is opened. Thus the admission in equilibrium is denoted by $x_{ij}^* = \arg\max \pi_i(x_{ij})$.

3.3 Investment in BC

In the first stage, each university decides whether to open a BC according to the competitor's strategy. The following table shows the payoff matrix according to whether university A and B decide to invest in a BC, and

$k \in \{1, 2\}$, where

$$k = \begin{cases} 1 \text{ for } t \leq t^* \\ 2 \text{ for } t > t^* \end{cases}.$$

		University B	
		BC	N
University A	BC	$\pi_{Ak}^{FF}; \pi_{Bk}^{FF}$	$\pi_{Ak}^{FN}; \pi_{Bk}^{FN}$
	N	$\pi_{Ak}^{NF}; \pi_{Bk}^{NF}$	$\pi_{Ak}^{NN}; \pi_{Bk}^{NN}$

Stage 1 Payoff Matrix

Superscript FF indicates that both universities open a BC, superscript FN denotes that University A opens a BC and University B does not. Conversely, superscript NF says that university A does not open a BC but university B does. Finally, superscript NN indicates that none of the universities open a BC. The subgame perfect equilibrium can be found according to values of the establishment (fixed) costs of opening a BC, F. This problem cannot be solved at this general level without imposing additional structure to the various functional relationships. In the remainder of the paper, we provide a detailed example in order to depict the characteristics of the equilibria.

4 An example

4.1 Students and universities

In this example we set $U(x_{ij}) > t$.[6] We begin by describing the students' behaviour. A student's utility function is:

$$U(x_{ij}) = wx_{ij} - f - T, \; i = A, B, \; j = 1, 2$$

[6]The results are qualitatively similar by considering $U(x_{ij}) < t$ and can be provided upon request.

where $w > 0$ is a parameter measuring the marginal impact of the admission standard on the graduate wage, and f denotes tuition fees, where $f < wx_{ij}$ for every i and j. For $T = 0$, a student either (i) lives in Country 1 and attends university, or (ii) lives and attends university in Country 2, i.e., at least one BC is opened. Conversely, for $T = t$, a student from Country 2 attends university in Country 1, t representing mobility costs. The wage of a student who does not attend university is normalised to zero, $U(0) = 0$.

Consider next universities. Each university decides whether or not to open a BC in Country 2 at a cost $F > 0$ and then it chooses the standard x_i. Therefore for each university $i = A, B$, the objective function is:

$$\pi_i = \sum_j^{1,2} (wx_{ij}n_{ij} + R_i) - \Phi_i, \tag{2}$$

where $R_i = fn_{ij} - c(n_{ij})$, with fn_{ij} the total budget given by the overall tuition fees and $c(n_{ij}) = c\sum_j^{1,2} n_{ij}^2$ is total teaching costs. Hence (2) can be rewritten as

$$\pi_i = \sum_j^{1,2} n_{ij}(wx_{ij} + f - cn_{ij}) - \Phi_i,\ i = A, B. \tag{3}$$

According to (3), a university's payoff is an increasing function of the number of graduates, its own admission standard, as well as the investment in research. Finally, we assume that the distribution of abilities in each population is uniform, so that $G(\theta) = \theta$. This allows us to explicitly calculate the number of admitted students in each university. Of course, this also depends on university A and B decisions about opening a BC. Lemma 1 shows the number of admitted students in equilibrium.

Lemma 1 *Let Assumption 1 hold. Then the number of students being ad-*

mitted to each university is:

$$n_A = \begin{cases} (1+\beta)(1-x_{A1}) & \textit{no BC} \\ (1-x_{A1})+(1-x_{A2}) & \textit{A BC} \\ (1+\beta)(1-x_{A1}) & \textit{B BC, A no BC for } t \leq t^* \\ (1-x_{A1}) & \textit{B BC, A no BC for } t > t^* \\ (1-x_{A1})+(1-x_{A2}) & \textit{B, A, BC} \end{cases},$$

$$n_B = \begin{cases} (1+\beta)(x_{A1}-x_{B1}) & \textit{no BC} \\ (x_{A1}-x_{B1})+\beta(x_{A12}-x_{B1}) & \textit{A BC} \\ \sum_j^{1,2}(x_{Aj}-x_{Bj}) & \textit{A and B, BC} \\ (1+\beta)(x_{A1}-x_{B1})+(1-\beta)(1-x_{B2}) & \textit{B BC, A no BC and } t \leq t^* \\ (x_{A1}-x_{B1})+(1-x_{B2}) & \textit{B BC, A no BC and } t > t^* \end{cases}.$$

4.2 Admission standards

In the second stage of the game, each university sets the admission standard i in each country j according to the following problem:

$$\max_{x_{ij}} \sum_j^{1,2} n_{ij}(wx_{ij}+f-cn_{ij})-\Phi_i. \tag{4}$$

In the Appendix we consider in full detail each possible case according to the decisions of opening a BC in the first stage and provide the solutions for admission standards and associated university payoffs. Based on these results, Lemma 2 below provides the critical value for mobility cost t^* that determines whether a student from country 2 will attend country 1 or not (see Definition 1)

Lemma 2 *A student from Country* 2 *with ability at least* θ_A *would either attend University A in Country* 1 *for all* $t \leq t^*$, *or attend the BC of University*

B for all $t > t^*$, where

$$t^* \equiv \frac{wc\beta(w+f)}{2(w+c)[w+c(1+\beta)]}.$$

Proof. See Appendix ■

Of course University A (B) prefers $wx_A - t \leq (>)\, wx_B$, as shown by:

$$\pi_{A1}^{NF} - \pi_{A2}^{NF} = \frac{\beta w(w+f)}{4(w+c)[w+c(1+\beta)]} > 0,$$

and

$$\pi_{B1}^{NF} - \pi_{B2}^{NF} = -\frac{\beta w^2(w+f)\left[w^2(4-\beta)+2wc(5+\beta)+c^2(6+4\beta)\right]}{16(w+c)^2(w+2c)} < 0.$$

4.3 Investment in BC

In this section we investigate the simultaneous choice of investing in a BC. For brevity, we consider Case 1 (relevant payoffs are given in the Appendix).[7] Begin by examining the strategy of university A according to university B decisions. If university B plays BC, university A would do the same for $\pi_{A1}^{FF} > \pi_{A1}^{NF}$, whereas if university B plays N, university A would play BC the same for $\pi_{A1}^{FN} > \pi_{A1}^{NN}$. Both these inequalities hold for all:

$$F < F_A \equiv \frac{(w+f)^2[w(1-\beta)+c(1+\beta)]}{4(w+c)[w+c(1+\beta)]}.$$

We now turn to the behaviour of university B. If university A plays BC, university B would do the same for $\pi_{B1}^{FF} > \pi_{B1}^{FN}$, which occurs for all:

$$F < \widehat{F}_B \equiv \frac{(w+f)^2(w+2c)^2[w(1-\beta)+c(1+\beta)]}{16(w+c)^3[w+c(1+\beta)]}.$$

[7] The computations of Case 2 are cumbersome, but bring about qualitatively similar results. Upon request, these results can be provided.

If university A plays N, university B would play BC the same for $\pi_{B1}^{NF} > \pi_{B1}^{NN}$, which takes place for:

$$F < \overline{F}_B \equiv \frac{w^3 (4-\beta)(1-\beta) + cw^2 \left(12 - \beta^2 (11-\beta)\right)(w+f)^2}{16(w+c)\left[w + c(1+\beta)\right]^3} +$$

$$\frac{4wc^2 (3-2\beta)^2 (1+\beta)^2 + 4c^3 (1+\beta)^3 (w+f)^2}{16(w+c)\left[w + c(1+\beta)\right]^3}.$$

Notice that the chain of inequalities of the threshold levels is $F_A > \overline{F}_B > \widehat{F}_B$. The following proposition shows which equilibrium type occurs depending on the values of w and F, according to the foregoing discussion.

Proposition 3 *Let $wx_i > t$ for all $i \in \{A, B\}$ and $t \leq t^*$. For all:*

[1] $F > F_A$, the equilibrium is (N;N);

[2] $F_A > F > \widehat{F}_B$, University A plays BC and University B plays N (equilibrium: (BC;N));

[3] $F < \widehat{F}_B$, the equilibrium is (BC;BC).

Figure 2 illustrates the equilibria given by the combination between the investment cost F and w for given β and c. It is easy to verify that the threshold $\overline{F}_B$ does not affect the Nash equilibrium. Also, notice that

$$F_A\big|_{w=0} = \widehat{F}_B\Big|_{w=0} = \frac{f^2}{4c}.$$

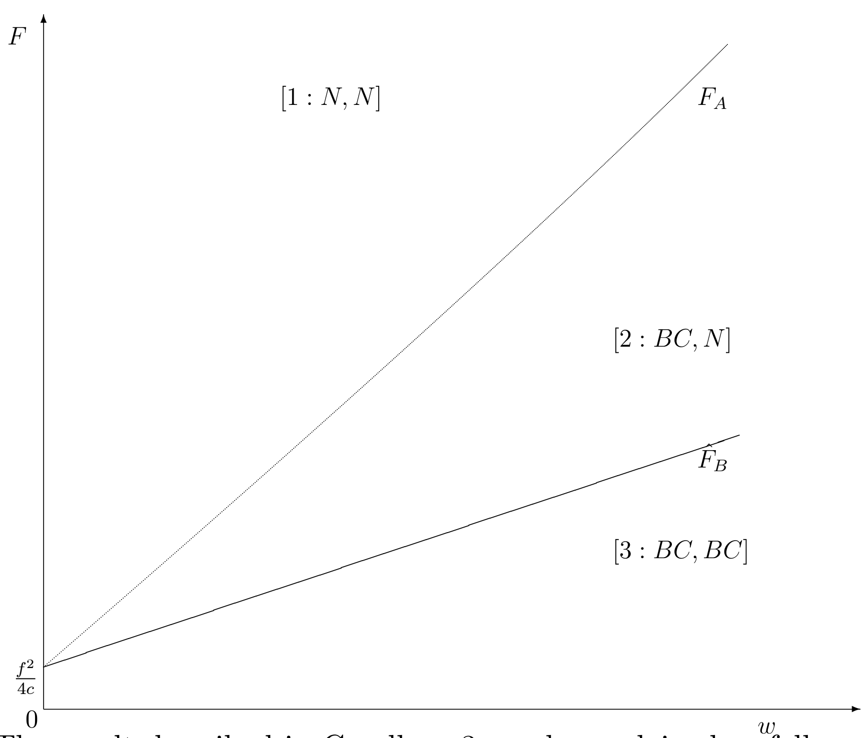
University A gains more from the students' qualification x than University B. Hence, the number of students n has relatively more importance in determining the B profits. Students prefer to attend University A, so that the demand for higher education is filled from that institution, whereas University B serves only the remainder of the demand for higher education. Therefore University A has more incentives in investing in BC, given the same cost F.

Consider next how a variation of the amount of privileged students may affect the equilibrium. Differentiating w^* with respect to β yields:

$$\frac{\partial}{\partial\beta}\left(F_A - \widehat{F}_B\right) = \frac{w^2\,(w+f)^2\,(3w+4c)}{16\,(w+c)^2\,[w+c\,(1+\beta)]} > 0.$$

Corollary 3 *An increase in the number of privileged students increases the probability that university A opens a BC while university B does not (equilibrium [2]).*

Figure 2: Equilibria



The result described in Corollary 3 can be explained as follows. A raise in the number of privileged students reduces the demand for university from students in the developing country. The non-elitist university is more affected by the fall in the demand relatively more than the elitist university, given the higher benefit from the latter from opening a branch campus.

5 Government intervention

This section considers the case in which the government of the developing country is willing to subsidise the introduction of branch campuses. The timing of the game changes in the following way (Figure 3): The first and second stage remain the same. Universities firstly decide whether or not to open a BC, and secondly set their admission standards. But now in the third stage, if a university opens a BC, then the government of the developing country will subsidise it with an amount given by the benefit in terms of increased students' graduate income.

Figure 3. The game timeline

Stage 1		**Stage 2**	**Stage 3**
Universities decide whether to open a BC	→	Universities set their admission standard	The government sets the level of subsidy

For the sake of tractability, in what follows we make two simplifying assumptions. First, tuition fees are set at the same level as the unitary cost of education, that is, $f = c$. Second, we consider the government problem from a partial equilibrium perspective, in the sense that we do not design a tax for providing the government the necessary resources for the university subsidies. As a justification for this, we posit that the tax covering the cost of subsidising universities is evenly paid by the population of the developing country, and it is irrelevant in a student's decision about whether or not to attend university. This assumption ensures that Lemma 1 still holds, by allowing us to avoid cumbersome and out-of-the context analytical issues. Finally as previously in the example we focus on Case 1, in which $t \leq t^*$.

In the third stage of the game, the government introduces a subsidy for universities willing to open a BC. The optimal subsidy m is given by equating the marginal benefit of subsidising universities (the salary of a graduate student w) with the marginal cost (the subsidy for one student, M/n_{i2}), so that $m = w$.

In the second stage of the game, each university sets the admission standard i in each country j according to the following problem:

$$\max_{x_{ij}} \sum_{j}^{1,2} n_{ij} \left(w x_{ij} + f - c n_{ij} + M_i \right) - \Phi_i,$$

where $M_i = m n_{i2}$ if a university opens a BC, and $M_i = 0$ otherwise.

Following the previous structure of the exposition, we consider separately each possible case according to the decisions of opening a BC in the first stage. For brevity, we will omit the derivation of the first order conditions. The case **No BC** is identical since no subsidisation occurs. Given $f = c$, the universities payoffs are:

$$\pi_A^{NN} = \frac{(w+c)^2 (1+\beta)}{4 \left[w + c(1+\beta) \right]},$$
$$\pi_B^{NN} = \frac{(w+c)^2 \left[w + 2c(1+\beta) \right]^2 (1+\beta)}{16 \left[w + c(1+\beta) \right]^3}.$$

University A BC: if university A opens a BC but not university B, the admission threshold in equilibrium is:

$$x_{A1}^{FN} = \frac{1}{2}$$
$$x_{A2}^{FN} = \frac{c}{2(w+c)},$$
$$x_{B1}^{FN} = \frac{w + 2\beta c}{4 \left[w + c(1+\beta) \right]}.$$

Notice that $x_{A1}^{FN} > x_{A2}^{FN}$. In other words, the admission requirements for the university in the developed country are higher than in the developing country.

Thus the universities payoffs are:

$$\pi_A^{FN} = \frac{5w^2 + 6wc + 2c^2}{4(w+c)} - F,$$
$$\pi_B^{FN} = \frac{(w+2c)(1+\beta)}{16[w+c(1+\beta)]}.$$

University A **and** B **BC:** if both universities open a BC, the admission threshold in equilibrium is:

$$x_{A1}^{FF} = \frac{1}{2},$$
$$x_{A2}^{FF} = \frac{c}{2(w+c)},$$
$$x_{B1}^{FF} = \frac{w}{4(w+c)},$$
$$x_{B2}^{FF} = -\frac{w(2w+3c)}{4(w+c)^2} < 0.$$

Since an admission standard cannot be negative, we set $x_{B2}^{FF} = 0$, implying full market coverage in Country B. Therefore the universities payoffs are:

$$\pi_A^{FF} = \frac{5w^2 + 6wc + 2c^2}{4(w+c)} - F,$$
$$\pi_B^{FF} = \frac{w^3 + 13w^2c + 24wc^2 + 8c^3}{16(w+c)^2} - F.$$

University B **BC:** remember that we are considering the case where $t \leq t^*$. The admission threshold in equilibrium is:

$$x_{A1}^{NF} = \frac{w + c(1+2\beta)}{2[w+c(1+\beta)]},$$
$$x_{B1}^{NF} = \frac{w + 2\beta c}{4[w+c(1+\beta)]},$$
$$x_{B2}^{NF} = \frac{2c^2 + wc(2-3\beta) - \beta w^2}{4(w+c)[w+c(1+\beta)]}.$$

Therefore the universities payoffs are:

$$\pi_{A1}^{NF} = \frac{(w+c)^2 (1+\beta)}{4 [w + c (1+\beta)]},$$

$$\pi_{B1}^{NF} = \frac{w^4 \left(17+\beta^2\right) + 2w^3 c [27 + \beta (20+\beta)]}{16 (w+c) [w + c (1+\beta)]} +$$

$$\frac{w^2 c^2 [65 + \beta (88 + 25\beta)] + 4wc^3 (1+\beta)(9+7\beta) + 8c^4 (1+\beta)^2}{16 (w+c) [w + c (1+\beta)]} - F.$$

Consider next the investment decision in BC in the first stage. Begin by examining the strategy of university A according to university B decisions. If university B plays BC, university A would do the same for $\pi_{A1}^{FF} > \pi_{A1}^{NF}$, whereas if university B plays N, university A would play BC the same for $\pi_{A1}^{FN} > \pi_{A1}^{NN}$. Both these inequalities hold for all:

$$F < F_A^{Gov} \equiv \frac{w^3 (4-\beta) + 2w^2 c (4+\beta) + wc^2 (5+3\beta) + c^3 (1+\beta)}{4 (w+c) [w + c (1+\beta)]}.$$

We now turn to the behaviour of university B. If university A plays BC, university B would do the same for $\pi_{B1}^{FF} > \pi_{B1}^{FN}$, which occurs for all:

$$F < \widehat{F}_B^{Gov} \equiv \frac{4c^4 (1+\beta) + 4wc^3 (5+3\beta) + 24w^2 c^2 + w^3 c (8-5\beta) - \beta w^4}{16 (w+c)^2 [w + c (1+\beta)]}.$$

If university A plays N, university B would play BC the same for $\pi_{B1}^{NF} > \pi_{B1}^{NN}$, which takes place for:

$$F < \overline{F}_B^{Gov} \equiv$$

$$\frac{w^5 (16-\beta+\beta)^2 + w^4 c\left(64+46\beta-\beta^2+\beta^3\right) + w^3 c^2 \left(100+143\beta+43\beta^2-2\beta^3\right)}{16(w+c)[w+c(1+\beta)]^3} +$$

$$\frac{w^2c^3\left(76+156\beta+93\beta^2+13\beta^3\right)+4wc^4\left(7+4\beta\right)\left(1+\beta\right)^2+4c^5\left(1+\beta\right)^3}{16\left(w+c\right)\left[w+c\left(1+\beta\right)\right]^3}.$$

The chain of inequalities of the threshold levels is still $F_A^{Gov} > \overline{F}_B^{Gov} > \widehat{F}_B^{Gov}$, so that the results with government intervention are qualitatively similar to the case with no government summarised in Proposition 3.

We are now in a position to compare the results in the two situations through the differences in the threshold levels. In order to do that, we need to set $f = c$ also for the non-government case. The differences between F_A^{Gov} and F_A, and between $\widehat{F}_B^{Gov}$ and $\widehat{F}_B$ yield:

$$F_A^{Gov} - F_A = -\frac{w\left(3w+2c\right)}{4\left(w+c\right)} < 0,$$

and

$$\widehat{F}_B^{Gov} - \widehat{F}_B = \frac{w\left(w^2-3wc-8c^2\right)}{16\left(w+c\right)^2} \geq 0 \text{ for } w \geq \widehat{w} \equiv \frac{c\left(3+\sqrt{41}\right)}{2},$$

respectively. The results can be summarised as follows.

Proposition 4 *A government intervention in the form of a subsidy has ambiguous results in influencing the opening a BC in the developing country at best while it reduces the probability of opening a BC at worst.*

Figure 4 illustrates. Notice that

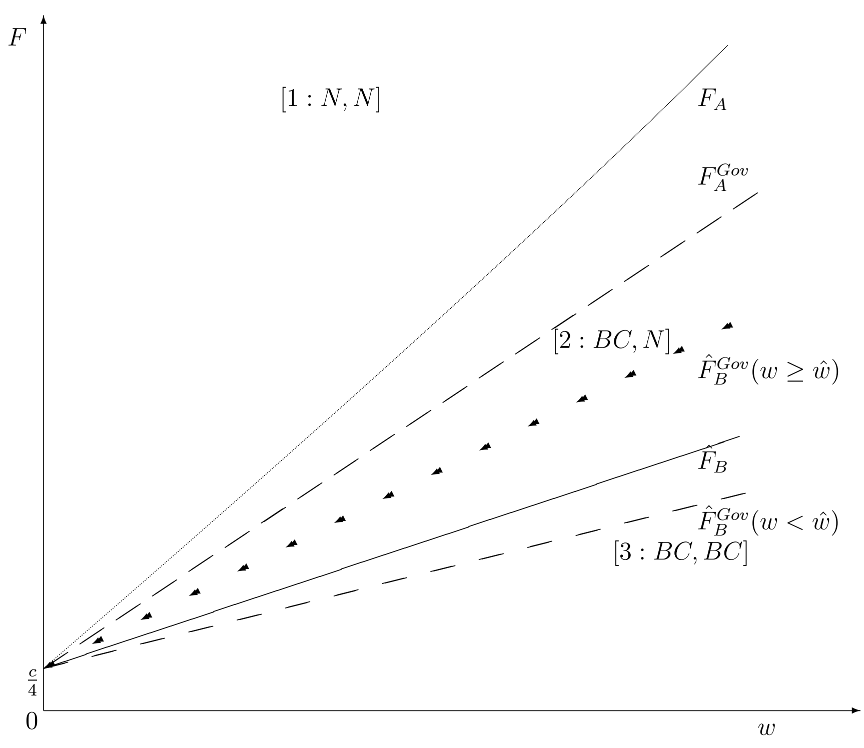
$$\left.F_A^{Gov}\right|_{w=0} = \left.F_A\right|_{w=0} = \left.\widehat{F}_B^{Gov}\right|_{w=0} = \left.\widehat{F}_B\right|_{w=0} = \frac{c}{4}.$$

The fact that $F_A^{Gov} - F_A < 0$ implies that a lower sunk cost is necessary in order to switch from equilibrium (N;N) to equilibrium (BC;N), whereas

$\widehat{F}_B^{Gov} - \widehat{F}_B < 0$ would indicate that a lower sunk cost is necessary to switch from equilibrium $(BC;N)$ to equilibrium (BC, BC). Therefore the introduction of government subsidies for opening BC are beneficial only if both (i) the graduate salary is quite higher than the cost of education and (ii) the sunk cost is not too high.

The intuition behind of Proposition 4 is the following. Since the elitist university gains more than the non-elitist university, the advantage of a subsidy whose marginal benefit is the same among universities relatively favours more the latter than the former. This lowers the incentive of University A to invest in BC. In turn, the lower incentive to University A may negatively affect the incentive of University B, in particular if the graduate salary is not much higher than the non-graduate salary.

Figure 4: Introduction of a subsidy



6 Concluding remarks

We have analysed competition among universities and its effect in opening a branch campus. Competition among universities from a developed country takes place by both setting admission standards and deciding whether or not to open a branch campus in a developing country. Students living in the developing country can attend university only if a branch campus is opened or if they can afford to move to the developed country. An increase in the graduate wages increases the incentives for opening a branch campus, although the incentive is stronger for the elitist than the non-elitist university. Three possible equilibria emerges: (i) no branch campus, when the investment costs are too high, (ii) a branch campus is opened by the elitist university only and (ii) two branch campuses. An increase in the proportion of privileged students increases the chance of an equilibrium of type (ii) to the detriment of equilibrium (i). A government subsidy for opening a branch campus may be ineffective in increasing university attendance in the developing country.

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A Appendix

A.1 Calculations - admission standards and payoffs

No BC: in the case where neither university A nor B open a BC, the first order conditions with respect to x_A, x_B are:

$$\frac{\partial \pi_A}{\partial x_{A1}} = (1+\beta)\left[w(1-2x_{A1}) + 2(1+\beta)c(1-x_{A1})\right] = 0,$$

$$\frac{\partial \pi_B}{\partial x_{B1}} = (1+\beta)\left[w(x_{A1}-2x_{B1}) + 2(1+\beta)c(x_{A1}-x_{B1})\right] = 0.$$

Solving yields the admission thresholds in equilibrium:

$$x_{A1}^{NN} = \frac{w+2c(1+\beta)-f}{2[w+c(1+\beta)]},\ x_{B1}^{NN} = \frac{w(w-3f)+4c^2(1+\beta)^2+4c(w-f)(1+\beta)}{4[w+c(1+\beta)]^2},$$

and the universities payoffs are:

$$\pi_A^{NN} = \frac{(w+f)^2(1+\beta)}{4\left[w+c(1+\beta)\right]},$$
$$\pi_B^{NN} = \frac{(w+f)^2\left[w+2c(1+\beta)\right]^2(1+\beta)}{16\left[w+c(1+\beta)\right]^3}.$$

Notice that

$$x_{A1}^{NN} - x_{B1}^{NN} = \frac{(w+f)\left[w-f+2c(1+\beta)\right]}{4\left[w+c(1+\beta)\right]^2} > 0.$$

University A BC: if university A opens a BC but not university B, the first order conditions with respect to x_A, x_B yield:

$$\frac{\partial \pi_A}{\partial x_{A1}} = (w+2c)(1-x_{A1}) - wx_{A1} - f = 0,$$

$$\frac{\partial \pi_A}{\partial x_{A2}} = (w+2c)(1-x_{A2}) - wx_{A2} - f = 0,$$

$$\frac{\partial \pi_B}{\partial x_{B1}} = (1+\beta)\left[(w+2c(1+\beta))(x_{A1}-x_{B1}) - wx_{B1} - f\right] = 0.$$

The admission threshold in equilibrium is then:

$$x_{A1}^{FN} = x_{A2}^{FN} = \frac{w+2c-f}{2(w+c)},$$
$$x_{B1}^{FN} = \frac{w(w-3f)+4c^2(1+\beta)+2c(w-f)(2+\beta)}{4\left[w+c(1+\beta)\right]^2}.$$

Thus the universities profits are:

$$\pi_A^{FN} = \frac{(w+f)^2}{2(w+c)} - F,$$
$$\pi_B^{FN} = \frac{(w+f)^2(w+2c)^2(1+\beta)}{16(w+c)^2\left[w+c(1+\beta)\right]}.$$

Notice that

$$x_{A1}^{FN} - x_{B1}^{FN} = \frac{(w+f)(w+2c)}{4(w+c)\left[w+c(1+\beta)\right]} > 0.$$

University A and B BC: if both universities open a BC, the first order conditions with respect to x_A, x_B are:

$$\frac{\partial \pi_A}{\partial x_{A1}} = (w+2c)(1-x_{A1}) - wx_{A1} - f = 0,$$

$$\frac{\partial \pi_A}{\partial x_{A2}} = (w+2c)(1-x_{A2}) - wx_{A2} - f = 0,$$
$$\frac{\partial \pi_B}{\partial x_{B1}} = (w+2c)(x_{A1}-x_{B1}) - wx_{B1} - f = 0.$$
$$\frac{\partial \pi_B}{\partial x_{B2}} = (w+2c)(x_{A2}-x_{B2}) - wx_{B2} - f = 0.$$

The admission threshold in equilibrium is:

$$
\begin{aligned}
x_{A1}^{FF} = x_{A2}^{FF} &= \frac{w+2c-f}{2\left(w+2c\right)}, \\
x_{B1}^{FF} = x_{B2}^{FF} &= \frac{\left(w+2c\right)^2 - f\left(3w+4c\right)}{4\left(w+c\right)^2},
\end{aligned}
$$

where the superscript indicates that both universities invest in BC. Therefore the universities payoffs are:

$$
\begin{aligned}
\pi_A^{FF} &= \frac{\left(w+f\right)^2}{2\left(w+c\right)} - F, \\
\pi_B^{FF} &= \frac{\left(w+2c\right)^2\left(w+f\right)^2}{8\left(w+2c\right)^3} - F.
\end{aligned}
$$

Notice that

$$
x_{A1}^{FF} - x_{B1}^{FF} = \frac{\left(w+f\right)\left(w+2c\right)}{4\left(w+c\right)^2} > 0.
$$

University B BC: as previously stated, in the case in which University B is the only one who sets a BC, then there are two possibilities according to whether $t \lesseqgtr t^*$. Consider first $wx_A - t \geq wx_B$ (i.e., $t \leq t^*$). In this case (Case 1), according to Lemma 1 demands for University A and B are:

$$
\begin{aligned}
n_A &= \left(1+\beta\right)\left(1-x_{A1}\right), \\
n_B &= \left(x_{A1}-x_{B1}\right) + \left(1-x_{A1}\right)\left(1-\beta\right) + \left(x_{A1}-x_{B2}\right).
\end{aligned}
$$

The first order conditions with respect to x_{A1}, x_{B1} and x_{B2} are:

$$
\frac{\partial \pi_A}{\partial x_{A1}} = \left(1+\beta\right)\left[\left(w+2c\left(1+\beta\right)\right)\left(1-x_{A1}\right) - wx_{A1} - f\right] = 0,
$$

$$
\frac{\partial \pi_B}{\partial x_{B1}} = \left(w+2c\right)\left(x_{A1}-x_{B1}\right) - wx_{B1} - f = 0,
$$

$$
\frac{\partial \pi_B}{\partial x_{B2}} = \left(w-2c\right)\left[1-\beta\left(1-x_{A1}\right) - x_{B2}\right] - wx_{B2} - f = 0.
$$

The admission thresholds in equilibrium are:

$$\begin{aligned}
x_{A1}^{NF}\left(t \leq t^{*}\right) &= \frac{w+2c\left(1+\beta\right)-f}{2\left[w+c\left(1+\beta\right)\right]}, \\
x_{B1}^{NF}\left(t \leq t^{*}\right) &= \frac{w\left(w-3f\right)+4c^{2}\left(1+\beta\right)+2c\left(w-f\right)\left(2+\beta\right)}{4\left(w+c\right)\left[w+c\left(1+\beta\right)\right]}, \\
x_{B2}^{NF}\left(t \leq t^{*}\right) &= \frac{4c^{2}\left(1+\beta\right)-w\left[f\left(2+\beta\right)-w\left(2-\beta\right)\right]+2c\left[3w-f\left(1+2\beta\right)\right]}{4\left(w+c\right)\left[w+c\left(1+\beta\right)\right]}
\end{aligned} \tag{5}$$

where the superscript indicates that university A did not invest in BC (N) and university B did (F). Therefore the universities payoffs are:

$$\begin{aligned}
\pi_{A1}^{NF}\left(t \leq t^{*}\right) &= \frac{\left(w+f\right)^{2}\left(1+\beta\right)}{4\left[w+c\left(1+\beta\right)\right]}, \\
\pi_{B1}^{NF}\left(t \leq t^{*}\right) &= \frac{\left(w+f\right)^{2}\left[8c^{2}\left(1+\beta\right)^{2}+4wc\left(3-\beta\right)\left(1+\beta\right)+w^{2}\left(5-\beta\left(4-\beta\right)\right)\right]}{16\left(w+c\right)\left[w+c\left(1+\beta\right)\right]}-F.
\end{aligned}$$

We then consider the case (Case 2) in which $wx_{A1}-t < wx_{B2}$ (i.e., $t > t^{*}$). In this case, the demands for University A and B are:

$$\begin{aligned}
n_{A} &= \left(1-x_{A1}\right), \\
n_{B} &= \left(x_{A1}-x_{B1}\right)+1-x_{B1}.
\end{aligned}$$

The first order conditions are:

$$\frac{\partial \pi_{A}}{\partial x_{A1}} = \left(w+2c\right)\left(1-x_{A1}\right)-wx_{A1}-f=0,$$

$$\frac{\partial \pi_{B}}{\partial x_{B1}} = \left(w+2c\right)\left(x_{A1}-x_{B1}\right)-wx_{B1}-f=0,$$

$$\frac{\partial \pi_{B}}{\partial x_{B2}} = \left(w+2c\right)\left(1-x_{B2}\right)-wx_{B2}-f=0.$$

The admission thresholds in equilibrium are:

$$
\begin{aligned}
x_{A1}^{NF}(t > t^*) &= \frac{w + 2c - f}{2(w + c)}, \\
x_{B1}^{NF}(t > t^*) &= \frac{(w + 2c) - f(3w + 4c)}{8(w^2 + 3wc + 2c^2)}, \\
x_{B2}^{NF}(t > t^*) &= \frac{w + 2c - f}{2(w + c)},
\end{aligned}
\tag{6}
$$

and universities payoffs are:

$$
\begin{aligned}
\pi_{A2}^{NF}(t > t^*) &= \frac{(w + f)}{4(w + c)}, \\
\pi_{B2}^{NF}(t > t^*) &= \frac{(w + f)^2 (5w^2 + 12wc + 8c^2)}{16(w + c)^3} - F
\end{aligned}
$$

A.2 Proof of Lemma 2

Proof. A student in Country 2 with ability equal or greater than θ_A is indifferent between moving to Country 1 to attend University A and attending the BC of University B if

$$
wx_{A1}^{NF}(t \leq t^*) - t^* = wx_{B2}^{NF}(t > t^*),
$$

which occurs for

$$
t^* = \frac{wc\beta(w + f)}{2(w + c)[w + c(1 + \beta)]}.
$$

Finally, it is necessary to verify that indeed below t^* the condition

$$
wx_{A1}^{NF}(t \leq t^*) - t > wx_{B2}^{NF}(t \leq t^*) \tag{7}
$$

holds and, accordingly, above t^* the condition

$$
wx_{A1}^{NF}(t > t^*) - t < wx_{B2}^{NF}(t > t^*) \tag{8}
$$

holds. Inequality (7) holds for all

$$t < \widetilde{t} \equiv \frac{w\beta\,(w+f)\,(w+4c)}{4\,(w+c)\,[w+c\,(1+\beta)]},$$

whereas inequality (8) holds for all

$$t > \widehat{t} \equiv 0.$$

Finally, notice that $\widehat{t} < t^* < \widetilde{t}$, thus the threshold t^* satisfies the conditions (7) and (8) along the entire parameter range. ■