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Navel gazing: Academic inbreeding and scientific productivity

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Abstract

The practice of having PhDs employed by the university that trained them, commonly called "academic inbreeding" has long been assumed to have a damaging effect on scholarly practices and achievement. Despite this perception, existing work on academic inbreeding is scarce and mostly descriptive or speculative. In this research we show, first, that academic inbreeding can be damaging to scholarly output. Our estimates suggest that academically inbred faculty generate on average 15% less peer reviewed publications than their non-inbred counterparts. Second, academically inbred faculty are more centered in their own institution and less open to the rest of the scientific world. In particular, we estimate that they are about 40% less likely to exchange information of critical relevance to their scholarly work with external colleagues. Third, academic inbreeding appears to be detrimental to scientific output even in leading research universities. Overall, our analysis implies that administrators and policy makers aiming to develop a thriving research environment in universities should seriously consider mechanisms to limit this practice. It also explores the role, importance and mechanisms by which outsiders contribute to create a dynamic and creative environment in knowledge intensive settings.

1. Introduction

At the beginning of the 20th century, it was common to find a large proportion of the faculty in major US land grant universities (McNeely, 1932) and in Ivy League institutions (Handschin, 1910) who

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had completed their PhD at the university where they were subsequently employed as faculty. This practice, commonly called "academic inbreeding" continues today in some US schools, especially the most prestigious ones (Burris, 2004). For example, the proportion of inbred entry level faculty at the Harvard Law School is 81%, and at the Yale Law School is 73% (Eisenberg and Wells, 2000). However, currently in the US, levels of academic inbreeding in universities are typically less than 20% and often below 10%. A similar situation is reported for other countries with developed scientific systems such as in the United Kingdom (Navarro and Rivero, 2001).But inbreeding is seen in many countries as “business as usual”, especially those with emergent scientific systems. Estimates suggest that academic inbreeding in Spain is as high as 95% (Navarro, A. Rivero, 2001); in Portugal it is 80% (Heitor and Horta, 2004). High rates have also been reported at French (Navarro and Rivero, 2001), Swedish (Bleiklie and Hostaker, 2004), Russian (Smolentseva, 2003), Mexican (Santibañez et al., 2005), Korean (Johnsrud, 1993), Chinese (Yimin and Lei, 2003) and Japanese national universities (Yamanoi, 2005).Furthermore, although measures to tackle this issue are being considered in some regions (e.g.: Bosch, 2006), they often generate fierce resistance (e.g. see Yimin and Lei, 2003)

Academic inbreeding has long been assumed to have a damaging effect on scholarly practices and achievement because it gives rise to academic parochialism (Berelson, 1960; Pelz and Andrews, 1966). But, despite this perception, research on inbreeding is scarce and existing work tends to be descriptive or exploratory, typically relying in univariate methods (Soler 2001, Wyer and Conrad 1984, Hargens and Farr’s 1973, McGee 1960). Yet, a growing presence of inbreeding environments, sometimes extreme, has raised critical questions as to the impact of this practice on universities (Navarro and Rivero, 2001; Soler, 2001) and, consequently in the development of innovation systems around the world.

A proper understanding of the impact of academic inbreeding is of direct interest to university administrators and policy makers in the area of science, technology and higher education. But the relevance is far more reaching. Universities have long been seen as central elements of a national innovation system and fundamental pillars in a knowledge based economy (Nelson 1993; Rosenberg and Nelson, 1994). The university research function in particular is of direct relevance for local industry innovation (e.g.: Henderson et al., 1998). For instance, Jaffe (1989) finds a positive relationship between university research expenditures and local patenting rates (see also Acs et al., 1992) while Nelson (1993) shows how countries with the strongest firms in several high tech sectors, had equally solid university research. More recent results have confirmed and expanded this notion. Among others, Spencer (2001) compares Japan and the US, confirming the importance of local university research output to the technical advance of domestic firms, while Zucker et al. (2006) show that the local presence of US stars scientists has a large positive effect on new firm entry in the same technology area. Furman and MacGarvie (2007) demonstrate that the growth of industrial pharmaceutical laboratories was driven by the extent of local university research. Thus, a negative impact of academic inbreeding in university research output and quality, will also be playing a critical limiting the role on scientific and economic outcomes of the region.

Studying the impact of academic inbreeding in scholarly practices is also relevant to further our understanding of the role of individual mobility in processes of knowledge generation in research environments. A budding literature in this topic suggests that hiring external researchers into existing environments is important for the ability of organizations to generate and access new knowledge. For example, Song et al. (2003) show that researcher mobility is more likely to result in interfirm knowledge transfer; Lacetera et al (2004) demonstrate that hiring star scientists can reshape the direction of research organizations. Looking at academic inbreeding helps reflect on what may happen to practices and outcomes of scientists that never change their research environment, as compared to those that are mobile.

The paper assesses the impact of academic inbreeding on scholarly practices and achievement by carefully analyzing detailed data on Mexican scientists, their characteristics, behaviors and outputs. Mexico's scientific system is particularly suitable to study the effects of academic inbreeding because its size, diversity and level of development make it a reasonable representative of many other emerging nations around the world (Veloso *et al.,* 2006). In addition, there is sufficient academic inbreeding to support a statistical analysis (see also Santibañez et al., 2005). The paper is organized as follows. The next section reviews the critical literature and presents the key hypothesis to be tested. Section 3 describes the data and empirical models to be used. Section 4 presents the results and section 5 concludes.

2. Literature and Hypotheses

In the beginning of the 20th century academic inbreeding was current in the United States, even in preeminent universities. Its potential dire effects were then already noted. The president of Harvard, Charles W. Eliot alerted that inbreeding presented "grave dangers for a university" (1908: 90) in a time when 64% of the university faculty were own graduates. Historical studies suggest that even then, inbred faculty had lesser recognition, both academic and economic, as well as lower levels of achievement and promotion when compared to non-inbreds (Eells and Cleveland, 1999; Reeves et al., 1933).

Existing research identifies two critical notions associated to the potential negative impacts of academic inbreeding, which were clearly established by Pelz and Andrews (1966) in their important sociological study of scientists. First, Pelz and Andrews (1966) stated that the main question of inbreeding rests on the idea that inbred faculty are less creative, independent, connected and original than non-inbred faculty. They argued in particular that inbreeding is associated with an exchange of scholarly information that favors internal sources over external contacts with other educational, scientific and societal institutions. The underlying statements of the authors imply a mechanism as well as a concern associated with academic renewal and adaptation to the evolution of knowledge. During their training, PhD students mainly assimilate the knowledge and learning environment of their institution, which they will largely use to inform future students when they become faculty (McNeely, 1932). Thus, when universities hire their own PhDs, there will be an overemphasis on the reproduction of locally learned knowledge, practices, as well as a consolidation of social structures in the organization. This may slow or block new or alternative approaches to the creation of institutional knowledge, limiting institutional change and ultimately contributing for the ossification of the organization (European Commission, 1995)

This notion is consistent with known processes of learning and socialization in organizations. Existing work suggests that search processes in knowledge intensive environments tends to be path dependent and localized (Nelson and Winter, 1982; Stuart and Poldony, 1996; Rosenkopf and Nerkar, 2001; Singh, 2005), while hiring of external researchers can open the organization to new knowledge (Song et al., 2003) and even entire new research directions (Lecetera et al., 2004). Moreover, it has also been shown that, as individuals are integrated in an organization, they become reproducers of the ideals of organizational culture (Frans *et al.*, 1999). While this socialization process permits an efficient use of knowledge, it may also constrain its scope and flexibility (Camerer and Vepsalainen, 1988). In extreme situations, it can originate the establishment of 'mental prisons' that impede change or slow it in favor of organizational and knowledge inertia (Leeuw and Volberda, 1996). This perspective matches precisely the concern expressed by Pelz and Andrews (1966).

Qualitative studies in the specific context of the university completed since Pelz and Andrews' work lend support to this notion. For example, in a study of Brazilian agricultural scientists, Velho and Krige (1984) suggest that a strong inbreeding trend is associated to low levels of communication between scientists, as well as to preferences to interact with institution colleagues rather than with colleagues from other universities and R&D units. Therefore, the first critical hypothesis is:

H1 - Information exchange hypothesis: "Inbred faculty more likely to exchange scholarly related information inside the university than non-inbred faculty"

The second critical notion of the literature, also articulated by Pelz and Andrews (1966), is that academically inbred faculty and their practices would ultimately lead to inferior scientific output when compared to non-inbred faculty. To understand why this might be the case, it is important to note that the generation of new knowledge in a university relies extensively on the creativity of the researchers. This requires ever more frequently the combination of a pool of existing and emergent knowledge (See Kogut and Zander, 1992; Fleming and Sorenson, 2004). The opportunities for knowledge combination are conditioned by a number of factors, including organization experience, expertise and frequency in exchanging information and knowledge (Nelson and Winter, 1982). The knowledge production process is also path dependent (Nelson and Winter, 1982) and strongly influenced by embedded and stable organizational routines (Baum et al., 2000). When a university mainly hires its own graduates, existing socially accepted programs of action are further consolidated. If these give lesser importance to external knowledge (Kogut and Zander, 1992; Stuart and Poldony, 1996) and to the demands of an increasing complex and fast evolving knowledge (Nowotny et al., 2001) then, as noted above, they may constrain the scope and flexibility of an organization (Camerer and Vepsalainen, 1988) and lead to knowledge inertia (Leslie and Fretwell, 1996). This will ultimately be reflected in the output and quality of the research work (Rosenkopf and Almeida, 2003; Rosenkopf and Nerkar, 2001)

This idea is consistent with the perspective that that openness and collaboration are of critical importance in the current research environment (Adams et al. 2005). These critical connections with outside sources of knowledge need to be searched, created and nurtured. Building up such external links takes time and effort because, among others, it us critical to establish trust within the networks to make them work (Levin and Cross, 2004). If inbreeding shunts these efforts, it will eventually have a detrimental effect in research performance. Velho and Krige's (1984) study noted above suggests precisely that inbreeding and its practices are the main reason for Brazilian agricultural science to lag behind the leading edge international research in the field. Related work points to the same concept. Pieper and Willis (1999) argue that a very high concentration of PhD origins of economists led to increasing inbreeding in the profession, as well as to a lesser innovative thinking and creativity in the field. Soler's (2001) analysis of 51 ecology or zoology departments around Europe finds a negative correlation between scientific productivity and inbreeding. Thus, the second hypothesis is:

H2 - Productivity hypothesis: "Inbred faculty produce fewer scholarly outputs than non-inbred faculty"

A related perspective on the impact of academic inbreeding is the possibility for heterogeneity across institutions to mediate the impact of such practices on productivity. Berelson (1960) stated that major research oriented universities always had a greater percentage of inbred percentage because of their almost monopolistic position as producers of doctorates. A number of studies have shown this to be a consistent phenomenon across countries (e.g.: Yamanoi, 2005 for Japan; Santibañez et al., 2005 for Mexico; Hagstrom, 1971, Burris, 2004 and Merritt and Reskin, 1997, for the USA). Yet, Berelson (1960) also suggested that inbreeding processes at these universities could be different from other schools, for example those focusing more on teaching, because of the specific organizational environment. First, inbred faculty in top research schools would be hired, not because of the familiarity and ties with the university they gained during the PhD, but rather because they were considered as the best resource to maintain the eminent scholarly status of the university (Berelson, 1960). Second, organizational culture in these major research oriented universities is also different. Hagstrom (1971) suggests research oriented departments (or universities) may be less affected by the potential negative impact of inbreeding on research productivity because they tend to be more 'cosmopolitan'. This feature highlighted by Hagstrom (1971) refers the relevance of social capital and specifically the importance of interaction with others as a form to articulate and foster the development of existing knowledge (Nahapiet and Goshal, 1998). Research requires collaboration with colleagues outside the institution to maximize resources, achieve critical mass or find complementary skills (Thornsteinsdottir, 2000), aspects that have become ever more relevant in the last decades (Adams et al., 2005). As a result, during the course of their graduate studies as well as during their academic career, inbred faculty in leading research schools would be exposed to an environment with greater quality, openness, collaboration and diversity in terms of ideas and practices which can minimize the negative effects of inbreeding. The third hypothesis is then:

H3 - Leading research oriented university hypothesis: "The negative effects of academic inbreeding on scholarly practices and output is mitigated in leading research oriented universities"

This hypothesis was investigated by Hargens and Farr (1973). Their findings suggest that inbred faculty produce fewer articles than their non-inbred colleagues at research-oriented universities and they do not surpass non-inbred faculty in less prestigious universities. Yet, the test had a number of limitations, including a very limited number of control variables, the use of data from American Men of Science (that tends to focus on distinguishable and notable scientists, thus, providing a skewed characterization of the scientist of the overall system), and also the use of faculty members only from natural sciences (e.g.: math, physics and chemistry). Precisely due to the limitations of Hargens and Farr's (1973) study, Wyer and Conrad (1984) further examined the relationship between institutional origin and productivity for the 1977 survey of the American Professoriate, encompassing 160 institutions from all major academic disciplines. They find that inbred faculty produced more than non-inbred faculty. However, the analysis again has a number of limitations. First, the authors do not isolate 'silver-corded' and continuous inbreeding (see methods of this paper below). Second, the work is based on a discriminatory analysis that compares between critical variables for inbred faculty vs a non-inbred faculty, with the corrections for experience done on the dependent variable and no controls for heterogeneity across areas and institutions.

3. Methods and data

3.1 Data Source and Characteristics

The dataset used in this study was generated through a survey conducted to analyze the impact of public policies in processes of institutional change within Mexican higher education institutions. The questionnaire, sponsored by CONACYT, the Mexican Science and Technology Foundation and directed by one of the authors, focused on the academic profession. It included questions on demographics, career mobility, work experience, work conditions, work satisfaction levels, academic socialization, including forms of interaction in the context of working activities, and scholarly results between 1999 and 2002, for all scientific areas and most institutions in the Mexican Higher Education System. The original dataset that resulted from this questionnaire is composed by 3861 faculty members of all scientific fields from 64 higher education institutions of the Mexican higher education system.

Given the purpose of our analysis, this dataset was filtered using three requirements. The first requirement was to include only faculty holding a PhD. The Doctorate degree is usually considered as the degree that enables an individual to start a scientific career (Golde and Doré, 2001). Moreover, this was critical for our analysis since, following the literature (e.g.: Berelson, 1960), the location of the PhD will become the critical sorting variable to distinguish inbred from non-inbred faculty. The second requirement was that only higher education institutions that granted doctoral degrees could be analyzed. This restriction is required because, if an institution could not grant doctoral degrees and the doctoral degree is the minimal academic requirement for our analysis, then all faculty in those institutions would be necessarily non-inbred. Finally the third requirement was that only institutions with both inbred and non-inbred faculty members were included. As explained below, the analyses look at the effects of inbreeding by disciplinary field and institution. Thus, by construction, higher education institutions without inbred faculty cannot be used in the analysis. After the filtering process, the database used in our study includes 414 academics in 14 higher education institutions.

In our analysis, we use the concept of faculty inbreeding proposed by Berelson (1960). This concept considers an academic to be inbred when he or she was first hired and developed the career in the very same higher education institution where his or her doctoral degree was obtained. In the database we constructed the inbreeding variable by crossing information from three questions in the original survey: one that asked in which institution the PhD was obtained; another that asked in which institution did the academic career started; and a third that asked in which institution is the academic currently based. Crossing the answers from these three questions minimizes the possibility of mistakenly categorizing as inbred faculty those holding a PhD from the same institution where they currently work but that have previously held a position in another school[4]. These are referred to in the literature as "silver cord" (Berelson, 1960) and they are sometimes used mistakenly in the literature as faculty inbreeds. It is important to indentify this group because previous studies indicate that silver-corded academics tend to be scholarly superior (Caplow and McGee, 1958; Calhoun *et al.*, 1990). Thus, their categorization as inbreeds can bias the results an analysis[5]. Given this characterization, academically inbred faculty represent 26% of our sample, albeit with strong variation across institutions and areas of knowledge.

3.2. Data: Academic Output Measures

Two critical notions are being considered for analysis. The first relates to which colleagues and institutions are privileged by inbred and non-inbred faculty as sources to exchange information related to their scientific activities. In the survey, information exchange practices included 5 categories: information exchange about research and teaching activities, information exchange about innovative subjects and

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[4] Researcher mobility in Mexico is very small. Therefore it is highly unlikely to have cases that start as inbred faculty, then leave to another school and finally return to their alma mater.

[5] E.g. Long et al. (1993) found that the effect of inbreeding on promotion was not significant. Yet, they did not differentiate between inbred and 'silver corded', which could explain their results.

articles, information exchange about equipment and research techniques, information exchange about financial sources for research, information exchange about publishing and diffusion of research results, and information exchange about job vacancies. For each of these categories, the survey asked the academic what was his or her level of intensity in information exchange for two internal locations and two external locations. The two internal locations were the research group to which the academic belonged and other academics within the university. The two external locations were academics and institutions from other national institutions and academics and institutions from institutions outside the Mexican science and higher education system. The information exchange intensity for all locations was reported by academics at four levels: never, rarely, sometimes and frequently (coded from 1 to 4).

To assess if faculty favored information exchange inside or outside the university where they currently work, we created a binary variable which is the result of a comparison of the answers regarding the two internal locations with those obtained for the two external locations. First, the two internal locations were combined into one score of information exchange intensity within the university by adding the scores for the two individual answers. The answers to the two external locations were similarly combined into one score of intensity of information exchange outside the university. Second, we establish the binary variable that signals whether external sources for information exchange are favored over internal ones by comparing the combined internal and external scores. If the external information exchange intensity score is greater than the internal one, then the binary variable takes the value of 1; otherwise it takes the value of 0. For example, if an academic responded that she frequently (4) exchanged information with her research group colleagues and frequently (4) exchanged information with her university colleagues and sometimes (3) exchanged information with other national colleagues and frequently (4) exchanged information with academics in international institutions. Then we consider that, although this academic exchanged information frequently inside and outside his or her institution, she still privileged internal information exchange and thus the binary value would be zero (internal is favored):

Internal: (research group) 4 + (own university) 4 = 8 which is greater than

External: (other national colleagues) 3 + (international colleagues) 4 = 7

However, whenever the sum of internal and external scores is equal, then high frequency is used as an additional parameter to determine orientation. A frequent exchange of scientific information is more valued than an exchange of information that happens only sometimes because it assumes stronger ties and a much more active and engaging participation with colleagues in a specific context. So, in the following example, it would be considered that the academic privileged exchanging information with colleagues outside the university (the binary value would be one) due to the presence of a frequent collaboration assessment on the external side, even though the overall score is the same:

Internal: (research group) 3 + (own university) 3 = 6 which is the same as

External: (other national colleagues) 4 + (international colleagues) 2 = 6

In some cases, there was no difference in the preference between internal and external intensity of information exchange for the academic, even with the frequency rule described in the paragraph above. These cases occurred when the intensity of information exchanged was reported to be the same for all sources (e.g.: all information exchange were reported as frequently) or when the score for internal and external sources was the same and symmetrical (e.g.: internal 5=3+2 *vs.* external 5=3+2). In the base analysis reported in the article, we did not consider these cases in the estimation. This explains the varying number of cases observed across the different information exchange categories (see Table 1)[6].

The descriptive statistics for the resulting information exchange variables are presented in upper rows of Table 1 below. As it can be observed, faculty favors internal exchange of information over external exchanges across all variables, which is reasonable. There is evidence that knowledge is

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[6] To make sure that our decision rule was not biasing the results, we performed a sensitivity analysis. This was done by running two analyses equivalent to those reported in this article, yet considering that (1) all tied information exchange scores were assumed to be favoring internal sources (zero in our binary variable) or the opposite, (2) assuming that all ties favored external sources (taking the value of one). The results from these regressions, not presented here but available from the authors, are consistent with those presented in the article.

localized (e.g.: Velho and Krige, 1984 for universities; Rosenkopf and Almeida, 2003 for firms), which is consisted with the idea that faculty talk more often to their colleagues than with those outside the school.

Table 1 – Descriptive Statistics for the Dependent variables used in estimation

INFORMATION EXCHANGE	**Obs**	**Mean**	**Std.Dev.**	**Min**	**Max**
Share of faculty that favors information exchange outside own university in what concerns:					
Innovative subjects and articles in your field	315	0.25	0.43	0	1
Publishing and diffusion research results	300	0.27	0.44	0	1
Research and teaching activities	340	0.16	0.37	0	1
Equipment sources and research techniques	306	0.23	0.42	0	1
Financial sources for research	296	0.21	0.41	0	1
Job opportunities	278	0.24	0.43	0	1
SCIENTIFIC OUTPUTS					
Number of articles in peer reviews journals	409	2.82	2.28	0	9
Number of consulting contracts (Government or private)	409	0.28	0.93	0	7
Number of prototypes and patents	409	0.12	0.52	0	6
Number of undergraduate thesis supervised	409	1.99	2.17	0	9
Number of master thesis supervised	409	1.41	1.54	0	6
Number of PhD thesis supervised	409	0.65	1.05	0	4

Note: All the values refer to totals for years 1999-2002.

The other notion explored in article relates to the performance of inbred and non-inbred faculty in what concerns the generation of scholarly outputs. The outputs considered in our analysis include the major functions associated with the mission of the university – teaching, research and outreach. The data for these variables is obtained directly from the questionnaire that asks each academic his or her output along each of the relevant dimensions between 1999 and 2002. Descriptive statistics are presented in the lower rows of Table 1 above. The variables associated with teaching are the number of thesis at undergraduate, master and PhD level supervised by the faculty (although at PhD level the output represents to a certain extent a mix between teaching and research). To characterize outreach work we use the number of consulting contracts and as well as the numbers of prototypes and patents[7]. We believe these two variables can cover a very broad range of outreach activities, from dispensing advice to firms and the government, more typical in social sciences and likely to be labeled as consultancy projects, to

[7] This variable mostly reflects prototypes rather than patents, which are still quite rare in Mexico - from 1999-2002 top research institutions in Mexico received a total of only 36 patents during the period (Conacyt, 2004).

technical subcontracts, often in the physical sciences and engineering, which may not be seen as consultancy but are likely to entail developing physical prototypes for a client. Research output is assessed using the number of articles in scientific peer reviewed journals. This measure of output is an established metric typically used in studies of scientific productivity (e.g. Wyer and Conrad, 1984; Levin and Stephan, 1991; Adams et al. 2005; Gonzalez-Brambila and Veloso, 2007). However, it also has limitations. First, journals may vary in quality. Thus, while controlling for journal quality would be a good refinement of our analysis, such data was not available in the instrument used for this research. Second, we are not covering other scholarly outputs of research, such as books and conference papers. Yet, these tend to be less consistent in nature and quality than peer reviewed journals and thus even more noisy measures of output than the one we are considering (Lewison, 2001).

3.3 Data: Control variables

In addition to the critical performance variables, the proposed assessment (see below for a detailed description of the methods used in the estimations) requires an important set of control variables. The objective is to make sure that we, when we estimate the impact of inbreeding on information exchange or scientific output, we do not wrongly attribute to inbreeding other factors that also likely to correlate with information exchange practices or scientific output. These control variables were determined based on previous literature related to research productivity in scientific and higher education systems (e.g.: Gonzalez-Brambila and Veloso, 2007; Levin and Stephan, 1991). Summary statistics for the relevant control variables are presented in Table 2 (a correlation table A1 is presented in appendix).

The first control variable considered in our analysis is years since first job in academia. This controls for the experience of single faculty in academia and scientific system. Time is a very important variable in academia because it is associated with scientific and academic working experience and refinement of skills as well as with the integration into social networks both at organizational and systemic levels. The average experience of the faculty in the sample is 20 years. It is relevant to note that, in line with previous literature (see Gonzalez-Brambila and Veloso, 2007; Levin and Stephan, 1991), years in academia will be considered with a linear as well as a quadratic term.

Table 2 – descriptive statistics - independent variables

Variables	Obs	Mean	Std. Dev.	Min	Max
Years since first job in academia	414	20.51	9.86	1	48
Years since first job in academia squared	414	517.8	425.6	1	2304
Male	414	0.63	0.48	0	1
Conduct/participate collective R&D project	413	0.77	0.42	0	1
Had funding to developed R&D in the last 3 years	369	0.80	0.40	0	1
Teaches graduate students only	414	0.05	0.22	0	1
Teaches undergraduate students only	414	0.24	0.42	0	1
Average number of students per class	409	23.17	12.53	0	60
Inbreeding	414	0.26	0.44	0	1

The second variable considered as a control is gender, which accounts for known differences in research productivity between genders. As it can be seen in Table 2, 63% of our sample are men. The third variable we considered is participation in collective R&D projects. This aims to control for the overall extent of integration and engagement of the faculty in scientific networks dealing with research. As it can be seen in Table 2, most faculty (77%) participates these type of projects. Still related to engagement in research activities, we also control for whether the faculty member received funding in the previous 3 years to support R&D projects (80% have received). This controls for heterogeneity in the availability of resources that support the generation of research outputs[8].

The variables teaching to undergraduate only (24%), teaching to graduate only (5%) or teaching to both undergraduate and graduate programs (the baseline), and average number of students per class (23.2) control for the type and amount of teaching effort that the faculty is subject to. These features are important because the literature in research productivity suggests that there is a negative relationship between undergraduate teaching and research outputs (Marsh and Hattie, 2002). Also, the insertion of these control variables also take into account McGee's (1960) study of the university of Texas findings, where it was identified that teaching loads were different between inbred and non-inbred faculty. Previous analyses of institutional inbreeding highlight the importance of considering these activities when studying the effects of inbreeding in scientific outputs (e.g.: Wyer and Conrad, 1984).

[8] Because the system is overwhelmingly dominated by public universities, salary practices are such that there are no significant pay differences across faculty for the same academic rank.

3.4 Methods used

The estimation of the impact of inbreeding on information exchange practices relies on a multivariate probit regression model (see Wooldridge, 2001) based on:

$$\Pr(Y_{ijk} = 1) = \Phi(x_{ijk}'\beta + \alpha_j + \delta_k)$$

where the dependent variable is Y_{ijk} represents the information exchange for individual i in university j for scientific area k. $Y_{ijk} = 0$ if exchanges within the institution dominate and $Y_{ijk} = 1$ if exchanges outside are prevalent (see data description above on how the zero and one are determined). The independent variables (x_{ijk}) include a dummy signaling academic inbreeding (zero for non-inbreds and one for inbreds), as well as all the relevant controls described before: years since first job in academia as well as years squared, gender, availability of research funding, teaching duties (undergraduate, graduate or both) and number of students per class, institution and area of knowledge.

In addition, as the equation above shows, there are fixed effects for institution (α_j) and scientific area (δ_k). These are relevant controls because different institutions and areas of knowledge will be associated with important heterogeneity in scientific performance and information exchange practices for both inbred and non-inbreds. For example, it is likely that UNAM, a large and very well known institution attracts better people for its ranks, both inbreds and non-inbreds, when compared to a smaller regional university. If this were the case, results on the comparison of productivities across institutions could be entirely driven by unobserved differences between the institutions, rather than the differences between inbred and non-inbred faculty in each school. This could generate misleading results. .

In deciding the scientific fields, we followed the differentiation proposed by ANUIES, the national association of higher education institutions on Mexico. The scientific fields considered in the estimation include natural sciences (it includes what is named in Mexico as “exact sciences”: mathematics, chemistry and physics), social and administration sciences, education and humanities, engineering and technology, health sciences and agrarian sciences.

The estimation for the impact of inbreeding on academic output requires a procedure that can handle a dependent variable that is non-negative and based on counts. One alternative is to use a Poisson regression. Yet, the problem is that the Poisson distribution restricts the variance of the dependent variable to be equal to the mean. Thus, the alternative approach that is typically considered is to perform an analysis using a negative binomial multivariate regression (see Wooldridge, 2001) based on:

$$P(Y_{ijk} = y_{ijk}) = F(x_{ijk}'\beta + \alpha_j + \delta_k)$$

Where F is negative binomial distribution, Y_{ijk} is the scientific output of academic i in institution j and scientific field k, X_{ijk} are the independent variables that vary across faculty, scientific field and institution; a_i are the institutional effects, δ_k: are the scientific field effects.

4. Main Findings

Table 4 presents the summary results for the research question on information exchange. The results provide a strong confirmation of the argument that inbred faculty collaborate and exchange less information outside their institutions and, as a result, are less integrated into national and international scholarly networks. Inbred faculty are roughly 40% less likely to exchange information with external colleagues in most information categories. For example, they are 52% less likely to exchange information about innovative subjects and articles with colleagues outside the university, 46% less likely to exchange information about research and teaching activities, as well as 43% less likely to exchange information outside in what concerns publishing and diffusion of research results when compared to non-inbred.

Table 4 - Effect of academic inbreeding on likelihood of information exchange outside own school

Probability of faculty to favor information exchange outside own university in what concerns:	**Sample Mean**	**Inbred Effect**	**Inbred Effect / Sample Mean**
Innovative subjects and articles	24.8%	**-12.8%*** **	**-52%**
Research and teaching activities	16.5%	**-7.6%** **	**-46%**
Publishing and diffusion of research results	27.0%	**-11.6%*** **	**-43%**
Equipment sources and research techniques	22.5%	**-8.8%** **	**-39%**
Financial sources for research	21.3%	**-5.3%* **	**-25%**
Job opportunities	24.5%	-3.7%	n.s.

Note: *n.s. – not significant; * p<0.1; ** p<0.05; *** p<0.01;* Results are marginal effects obtained from regression estimation The ratio of the inbred effect over the sample is a direct algebraic estimation. Detailed regression results in appendix table A2.

This lack of connectivity with the exterior of the university lends support to the view that that inbred faculty contribute to the organizational stagnation of knowledge. By favoring to internal scholarly information exchange, the university pool of knowledge is not steadily renewed and can eventually be driven to exhaustion. The potential effect can be described by the words of Cohen and Levinthal's: "If all actors in the organization share the same specialized language…they may not be able to tap into diverse external knowledge sources" (1990: 133). Since knowledge depreciates (Argote, 1999), a university with many inbred faculty will have a reduced flow of external knowledge, leading to an increasingly outdated knowledge, thus and making the university become ossified and less responsive to a fast evolving and challenging knowledge based society (see also Hoare, 1994). This is consistent with Pelz and Andrews (1966) argument that inbred faculty are less creative, independent and original.

Table 3 - Effect of academic inbreeding on academic output

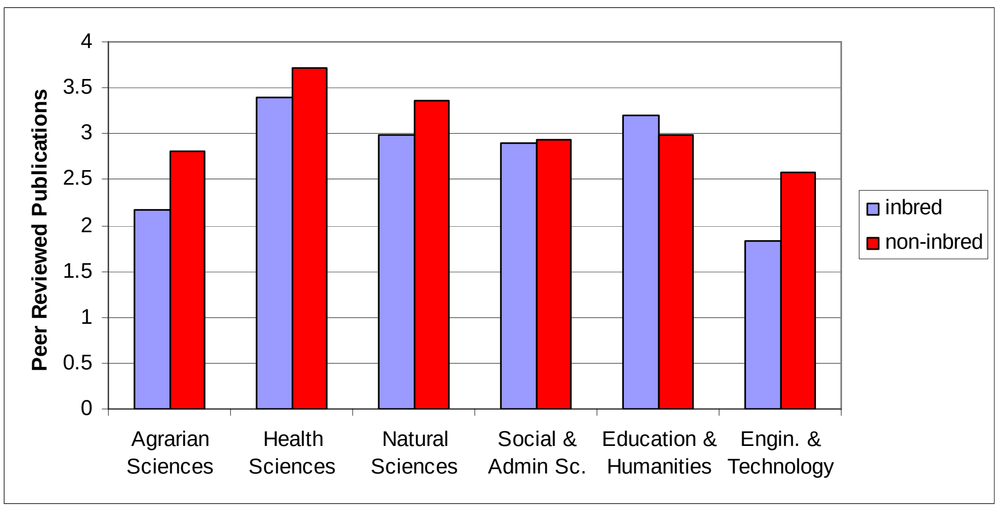
Impact of academic inbreeding in academic output measured as:	**Sample Mean**	**Inbred Effect**	**Inbred Effect / Sample Mean**
Number of articles in peer reviews journals	2.82	**-0.41****	**-15%**
Number of consulting contracts (Gov. or private)	0.28	**0.13*****	**46%**
Number of prototypes and patents	0.12	**0.01*****	**8%**
Number of undergraduate thesis supervised	1.99	-0.04	n.s.
Number of master thesis supervised	1.41	-0.09	n.s.
Number of PhD thesis supervised	0.65	0.03	n.s.

Note: *n.s. – not significant; * p<0.1; ** p<0.05; *** p<0.01;* Results on the table are marginal effects from regression estimation. The ratio of the inbred effect over the sample is a direct algebraic estimation. Regression results in appendix table A3.

The analysis also confirms that academic inbreeding influences the various scholarly outputs. Table 3 summarizes the key results concerning the relation between inbreeding and scholarly outputs. Results show that academic inbreeding has no impact on the production of teaching outputs as no statistically significant differences are found for the teaching output variables. This does not necessarily mean that inbreeding does not have an impact on teaching and learning processes. Inbreeding may affect teaching practices, but if that effect exists, then it is not perceived through the number of thesis supervised. However, a statistically significant difference in research production is identified, with inbred faculty generating, on average, 15% fewer scientific papers than non-inbreds. This productivity gap persists across most areas of knowledge, albeit with different intensities as Figure 1 shows.

Interestingly, the results on scientific productivity contrast with those concerned with the outreach mission of the university, which we proxy through the number of consultancy contracts as well as generation of prototypes and patents. Inbred faculty appear to be more involved in outreach activities, generating 46% more consultancy contracts and 8% more prototypes and patents than their non-inbred peers. These results suggest that a 'specialization' trend' between inbred and non-inbred faculty may be present. In a system with scarce resources, such as is the Mexican higher education system (Varela, 2006), individuals may be directing their efforts strategically to activities that allows them to better mobilize resources, according to the capabilities and skills that they have (Pfeffer and Salancik, 1978). It is possible that non-inbred faculty are dedicating their resources and activity strategy to scientific activities and funding while inbred-faculty are relatively more devoted to consultancy and other non-research work. Overall, the results confirm the perceived notion in the literature that academic inbreeding practices are detrimental for the production of scientific outputs.

Figure 1 - Predicted values for faculty scientific output between 1999 and 2002



Note: Numbers reported are predicted values from the negative binomial regression model.

Despite these results, as explained above, it is possible that inbreeding practices are moderated by the nature of the institution, such that in leading research oriented universities academic inbreeding would not be as damaging to scholarly activities. To test third hypothesis we look at the production of scholarly outputs for one of the largest and most prominent research university in Mexico: the *Universidad Nacional Autónoma de México* (UNAM). In Table 5, we report the results comparing inbred and non-inbred faculty at UNAM in terms of scholarly output. Results show that inbred faculty to produce fewer papers in reviewed journals when compared with their non-inbred colleagues. The effect nevertheless is smaller than for the overall sample, on average less 6% peer reviewed publications[9]. The trade-off with outreach activities appears to continue to exist, with mixed quantitative results: the dedication to consulting contracts is relatively larger for the UNAM sample when compared to the overall results but there are not enough observations on prototypes and patents to have a consistent estimation.

Table 5 – Effect of inbreeding on scholarly academic output at UNAM

Impact of academic inbreeding in academic output measured as:	**Sample Mean**	**Inbred Effect**	**Inbred Effect / Sample Mean**
Number of articles in peer reviews journals	3.03	**-0.19***	**-6%**
Number of consulting contracts (Gov. or private)	0.41	**0.29*****	**70%**
Number of prototypes and patents (1)	--	--	--
Number of undergraduate thesis supervised	2.08	-0.01	n.s.
Number of master thesis supervised	1.53	-0.11	n.s.
Number of PhD thesis supervised	0.87	0.16	n.s.

Notes: *n.s. – not significant; * p<0.1; ** p<0.05; *** p<0.01;* Results reported are marginal effects. Ratio of inbred effect over the sample is a direct algebraic estimation. (1) Number of events is not enough to ensure the validity of the statistical model for the "Number of prototypes and patents" variable (Wald test not significative) Detailed regression results in appendix table A4

These results support the third hypothesis and offer a partial confirmation of Berelson (1960) and Hagstrom's (1971), suggestion of the 'cosmopolitan' effect in more research oriented universities. Yet, even if to a less extent, academic inbreeding is still detrimental to the production of scientific outputs. Inbreeding seems to be a good policy if the university wants to increase its outreach mission through consulting contracts. As Table 5 indicates, inbreds are clearly more engaged in consultancy activities than non-inbred faculty.

5. Discussion

The analysis shows that inbreeding has a detrimental effect on research productivity of academic institutions. Universities, as major centers of knowledge production and accumulation play a central role in the process of innovation and technological progress (Bok, 2003; Rosenberg and Nelson, 1994).

[9] We assessed differences in information exchange practices for UNAM. But the Chi2 statistics for the regressions were mostly not significant. Results, although not significant, suggested no difference in information exchange practices between inbred and non-inbred faculty.

Research, the activity most affected by inbreeding, it is exactly the one that brought the university from its previous role of transmitting status quo knowledge, to an organization that actively pursued new knowledge (Graham and Diamond, 1997). It was also the research function of the university that led the university to be engaged in multi-organizational frameworks of knowledge production, governance, transmission and even commercialization (Audretsch and Stephan, 1996; Jaffe 1989; Feldman et al., 2002; Etzkowitz, 2003; Furman and MacGarvie, 2007). Thus, the negative impact of inbreeding on scientific output suggests far reaching implications for the competitiveness of a region. This is particularly important for countries still working to enhance their scientific base because universities represent an even more critical role as generators and processors of knowledge (Heitor and Horta, 2004).

Besides demonstrating the negative impact that inbreeding can have on scientific outcomes, it is also important to note that an excessive focus on internal information sharing is a critical element associated with this outcome. Openness and linkages to external sources are as important for the university as for any other organization. They allow the organization to understand what are the rules of the game (North, 1990), but also to identify where are resources available (Pfeffer and Salancik, 1978) and, of special interest to our particular context, to know where and how to learn and accumulate knowledge from (Nelson and Winter, 1982; Cohen and Levinthal, 1990). The generation of new knowledge requires combining existing and emergent knowledge, with most of the latter existing outside the organization (Kogut and Zander, 1992; Fleming and Sorenson, 2004). Thus, favoring internal knowledge exchanges preserves the existing institutional culture and status quo, leading to intellectual and organizational inertia (Leslie and Fretwell, 1996). This will ultimately be reflected in the output and quality of the research work (Rosenkopf and Almeida, 2003; Rosenkopf and Nerkar, 2001)

A related perspective is to look at the inbreeding problematic in terms of the learning process of faculty members in universities and the application of new knowledge, methods and organizational frameworks while developing their scholarly activities. Organizations learn at different paces (Pisano et al., 2001) and, as noted in the paragraph above, access to information and networks is critical for knowledge producing organizations such as universities to generate their scholarly activities and scientific outputs. Thus, inbreeding will make organizations learn at a slower pace and be less effective at analyzing their institutional environment. As a result, they become increasingly rigid and inertial, increasing the chances of not meeting its associated social goals and placing their social utility and perhaps even their legitimacy in jeopardy (Scott, 1995).

In this context, it is important to relate the findings of this work to the literature underlining personnel mobility as beneficial for the generation of knowledge (e.g.: Gruenfled et al., 2000) and its transference (Almeida and Kogut, 1999). Consistent with Song et al. (2003) and Lacetera et al. (2004), our results suggest that hiring faculty and recent doctorates from other universities brings outside linkages that are associated to new methods, as well as novel forms of thinking and doing research. Yet, our analysis goes further, showing that differences in mobility strategies are reflected in levels of productivity, while also advancing that information exchange practices are a key mechanism that may help understand such differences. Similarly, while previous authors (e.g. Rosenkopf and Nerkar, 2001) have found that accessing knowledge across organizational boundaries can have a positive impact on outcomes, our work goes beyond and provides a link to individual practices and outcomes, rather than posing it as an abstract organizational process. This opens new questions to the literature on further exploring the role of individual practices on its contribution to and impact in new knowledge generation.

Finally, when reflecting on this question, it is important to note that there may be strategic reasons for the presence of academically inbred faculty, even if its negative consequences on scientific outputs are recognized. In fact, some argue that academic inbreeding is an integrant part of the development process of any higher education system. This was first implicitly considered by McGee (1960) in his study of the University of Texas in the late 1950s. His conception was that academic inbreeding was part of an institutional strategy to overcome geographic and financial handicaps related to academic recruitment. According to him, differences in salaries between inbred and non-inbred faculty were used as a resource management strategy, positively discriminating non-inbred faculty so that it could be competitive in the higher education labor market and attract faculty with higher scholar (and especially research) potential. Non-inbred faculty were also given a lower teaching load, which helped them achieve a higher scientific productivity (the relation between time in teaching and research productivity is taken as negative; see Marsh and Hattie, 2002). Thus, they were also more likely to move faster in their career. In this context, faculty inbreeding can be associated with university efforts to gain competences when departing from a disadvantaged position. Inbreeding in leading research universities can also be present and be less damaging to scientific outputs because of their more cosmopolitan environment. Finally, since inbred faculty appear to be more engaged in outreach activities, universities may consider their presence when interested in promoting this dimension of their activity. Still, they need to realize that there will be a trade-off with their scientific outputs.

6. Conclusions

The analysis shows that academic inbreeding is detrimental to scientific productivity. Inbred faculty produce less articles in reviewed journals than non inbred faculty. Moreover, this finding appears to be related with the fact that inbred faculty favor internal exchange of information over external exchange of information. This means that, as universities grow the proportion of inbred faculty, there will be increasingly less openness and more internal focus. The analysis also shows that at leading research oriented universities inbred faculty still produce fewer peer reviewed articles, though the difference is smaller than in the complete sample.

The results suggest that an excessive dependence from inbred talent can easily lead to academic fossilization and knowledge atrophy. These are hand in hand with a resistance to the implementation of new methods, theories and flexible forms of organization. Universities that rely on this type of human resources are more likely to be rigid institutions, because closed groups tend to consolidate and reinforce existing social structures over adapting new ones. This is particularly dangerous for the university as an organization because rigid structures favoring inertia may unable them from being responsive towards society requirements, and therefore, lose legitimacy (Scott, 1995). Any organization that loses legitimacy (socially given) places its survival at risk.

Although not explored in this paper for lack of data (no citation data for the published papers), we anticipate that the quality of the scientific outputs produced by inbred faculty may also be lesser when compared with non-inbred faculty. In fact, previous work demonstrated that inter-institutional collaboration, not only impacted scientific productivity but also quality (e.g.: Adams et al., 2005). In any case, our analysis strongly asserts that inbreeding recruitment practices are detrimental to the development of the university knowledge base and therefore, should be limited or prevented. This leads us to assert that a periodical renewing of the faculty core is beneficial and necessary to recycle the learning and the organizational structure of the university, both research and teaching oriented. One way to undertake such strategy is to provide strong incentives towards mobility related to career progress, as well as to promote greater research productivity (e.g.: Dietz and Bozeman, 2005); another is by increasing internal competition, which is proved to lead to a valuation and use of external knowledge sources when compared to internal knowledge sources (Menon and Pfeffer, 2003).

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	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Under thesis (1)	1.00														
Master thesis (2)	-0.01	1.00													
PhD thesis (3)	0.00	0.31	1.00												
Articles peer reviewed journals (4)	0.27	0.02	0.07	1.00											
Prototypes and patents (5)	0.09	0.00	-0.06	-0.10	1.00										
Consulting Contracts (6)	0.03	0.12	0.22	0.03	0.08	1.00									
Research and teaching activities (7)	0.04	0.05	0.08	0.15	-0.08	-0.05	1.00								
Innovative subjects and articles in your field (8)	0.09	0.08	0.05	0.16	-0.11	-0.03	0.70	1.00							
Equipment sources and research techniques (9)	0.04	0.02	0.02	0.15	-0.10	-0.02	0.64	0.84	1.00						
Financial sources for research (10)	-0.01	0.05	0.03	0.19	-0.09	0.06	0.60	0.60	0.59	1.00					
Publishing and diffusion research results (11)	-0.04	0.04	0.03	0.09	-0.11	-0.03	0.70	0.72	0.67	0.60	1.00				
Job opportunities (12)	0.11	-0.03	0.14	0.18	-0.11	0.07	0.58	0.58	0.52	0.49	0.54	1.00			
Inbreeding (13)	0.13	-0.13	-0.06	-0.11	0.11	0.12	-0.15	-0.26	-0.21	-0.18	-0.19	-0.18	1.00		
Years since first contract (14)	0.07	0.24	0.29	-0.12	0.06	0.22	-0.05	0.10	-0.01	-0.04	-0.04	0.03	0.10	1.00	
Years since first contract squared (15)	0.05	0.19	0.29	-0.14	0.06	0.24	-0.07	0.10	-0.03	-0.07	-0.06	-0.01	0.12	0.96	1.00
Gender (male) (16)	0.10	0.16	0.06	0.19	0.21	0.13	0.04	0.00	-0.03	0.04	0.00	-0.01	-0.03	-0.01	-0.02
Participate collective R&D project (17)	0.06	0.04	0.20	0.14	-0.15	0.04	0.04	0.03	0.07	0.05	-0.03	0.07	-0.13	-0.12	-0.13
Funding for R&D last 3 years (18)	0.20	-0.03	0.11	0.15	0.10	0.04	0.01	0.01	-0.06	-0.08	-0.09	-0.05	0.05	0.01	0.01
Taught undergraduate only (19)	-0.02	-0.32	-0.25	-0.16	-0.02	-0.05	-0.10	-0.12	-0.06	-0.08	-0.08	-0.15	0.02	-0.17	-0.15
Taught graduate only (20)	-0.18	0.10	-0.08	-0.08	-0.06	0.09	0.16	0.19	0.20	0.22	0.19	0.12	-0.09	-0.03	-0.02
Average number students taught (21)	0.12	-0.15	-0.17	-0.04	-0.15	-0.12	-0.12	-0.02	-0.08	-0.12	-0.07	-0.16	0.09	-0.04	-0.08
Engineering and technology (22)	0.04	0.25	-0.05	-0.07	0.02	0.15	-0.18	-0.23	-0.21	-0.15	-0.19	-0.14	-0.03	0.01	0.02
Education and human sciences (23)	-0.04	0.02	-0.01	-0.03	0.02	0.08	0.07	0.07	0.08	0.10	0.22	0.07	0.07	0.02	0.01
Social and administrative sciences (24)	0.04	-0.04	-0.03	0.04	-0.11	-0.03	0.09	0.18	0.09	0.12	0.08	0.09	0.02	0.14	0.22
Natural and exact sciences (25)	-0.09	-0.15	-0.02	-0.02	0.09	-0.14	0.05	0.07	0.09	0.00	0.00	0.01	-0.05	-0.08	-0.15

Table A1 – Correlation table

	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)
Gender (male) (16)	1.00									
Participate collective R&D project (17)	-0.04	1.00								
Funding for R&D last 3 years (18)	0.21	0.13	1.00							
Taught undergraduate only (19)	-0.07	-0.03	0.01	1.00						
Taught graduate only (20)	-0.03	-0.02	-0.20	-0.12	1.00					
Average number students taught (21)	-0.14	0.08	0.07	0.07	-0.10	1.00				
Engineering and technology (22)	0.29	-0.26	-0.01	0.06	0.12	-0.21	1.00			
Education and human sciences (23)	-0.03	0.06	-0.18	-0.09	0.02	0.03	-0.18	1.00		
Social and administrative sciences (24)	-0.19	0.01	-0.08	-0.07	0.00	-0.10	-0.20	-0.14	1.00	
Natural and exact sciences (25)	-0.02	0.11	0.11	0.07	-0.06	0.15	-0.42	-0.30	-0.33	1.00

Table A1 – Correlation table (continuation)

	research and teaching activities	innovative subjects or published materials	equipment, sources and research techniques	financial aid for research	publishing and diffusion opportunities of research results	Work opportunities
Inbreeding	-0.344**	-0.425***	-0.322**	-0.188*	-0.373***	-0.122
Years since first contract	0.001	0.001	-0.046	0.012	0.015	0.011
Years since first contract squared	0.0001	0.0001	0.0007	-0.0004	-0.0005	-0.0001
Male	0.222	0.171	0.328**	0.172	-0.208*	0.195
Participate collective R&D	0.369	0.325	0.402*	0.315	-0.254	0.595**
Funding for R&D last 3 years	0.212	0.084	0.041	0.289	0.152	-0.099
Teaches graduate students only	-0.068	-0.441***	-0.308*	-0.043	-0.248	-0.454**
Teach undergrad students only	0.614**	0.328	1.279***	0.600**	0.173	0.320
Number of students per class	-0.005	-0.004	-0.001	-0.005	-0.008	-0.003
Engineering and technology	-0.741**	-0.785***	-0.590	-0.544**	-0.299	-0.815***
Educational and Human sciences	0.235	-0.002	-0.007	-0.124	0.487**	-0.139
Social sciences & administration	-0.501	0.0614	0.331*	-0.0189	-0.0352	-0.262
Natural and exact sciences	-0.001	-0.214	-0.109	-0.324*	-0.087	-0.413*
hei3	0.965***	-0.769**	-1.710***	-0.366**	0.161	0.282
hei19	-0.0530	-0.520**	-0.607***	-0.128	-0.231	-0.243
hei21	0.426**	0.260	-0.460	-0.177*	0.287**	0.398***
hei22	2.068***		0.540		1.275***	0.654*
hei23	0.0651	0.234***	0.310***	0.234***	0.286***	0.438**
hei42	-0.124	0.0182	-0.184	0.501***	0.624***	0.286
hei51	0.294**	0.341**	0.0893	0.305***	0.310**	1.251***
hei56	0.157	0.556**	0.279	0.231	0.891***	-0.0783
hei63	1.319***	1.162***	1.500***	0.568***	1.427***	1.312***
hei68	0.475***	0.360***	0.242**	-0.0327	0.844***	0.00415
hei75				-0.257**		0.984***
hei28	0.501*	0.467*	0.143	0.0710	-0.0410	0.197
hei84						0.256*
Constant	-1.475***	-0.924*	-0.601	-1.146***	-0.317	-1.195**
Wald (chi2)	410.56***	728.65***	1362.91***	96.61***	140.08***	6210.77***
Observations	291	267	262	263	260	247

Table A2 – Regression for *The information exchange hypothesis* *(heiXX represent individual university controls)*

	Supervision of undergrad thesis	Supervision of master thesis	Supervision of PhD Thesis	Articles in peer review journals	Consultancy (gov. or firms)	Prototypes and patents
Inbreeding	-0.021	-0.074	0.096	-0.150**	1.007***	0.749***
Years since first contract	0.026	0.051***	-0.013	-0.020*	0.057	-0.099
Years since first contract squared	-0.001*	-0.001**	0.001	0.0002	-0.0001	0.003**
Male	0.009	0.311***	0.176	0.155***	0.842*	1.262***
Participate collective R&D project	0.126	0.411	0.752***	0.266***	0.612*	-0.138
Funding for R&D last 3 years	0.055	0.047	0.589**	0.242***	-0.371	0.879**
Teaches graduate students only	-0.115	-0.718***	-0.960***	-0.267***	0.468	-0.020
Teaches undergraduate students only	-0.028	0.479**	-0.233	-0.132	0.515	-0.252
Average number of students per class	0.009	-0.004	-0.013***	0.001	0.007	-0.020
Engineering and technology	0.338***	0.027	-0.529**	-0.463***	1.576***	-0.031
Educational and Human sciences	0.172	-0.149	-0.384	-0.152	0.733	-0.194
Social sciences and administration	0.566***	-0.241	-0.374	-0.150	1.418***	-1.401***
Natural and exact sciences	-0.142	-0.430***	-0.569**	-0.213**	0.162	0.287
hei3	-2.171***	0.465***	-0.176	0.255*	-0.973	-14.050***
hei19	0.053	-0.112	0.367***	0.295***	-0.263	-14.560***
hei21	0.159*	0.117	-0.577***	-0.016	-0.974***	-1.0340***
hei22	-1.593***	0.001	-0.513**	-0.778***	-0.765	-13.520***
hei23	-0.056	0.044	0.193***	0.135***	-1.488***	0.614***
hei28	-0.316***	-0.318**	-0.644***	-0.536***	0.177	-14.100***
hei42	0.040	0.050	-1.607***	-0.456***	-1.047***	0.789***
hei51	0.251***	-1.038***	-0.334***	0.008	-0.877***	0.979***
hei56	-1.061***	0.085	-0.745***	-1.337***	-0.427	1.102***
hei63	0.170	-0.045	-0.967***	0.008	-0.070	0.179
hei68	0.377***	-0.070	-0.958***	0.035	1.228***	-15.11***
hei75	0.472***	0.321***	0.188	-0.502***	2.249***	0.784**
hei84	0.312***	-0.149**	-19.29***	0.989***	-17.67***	-14.57***
Constant	-0.032	-0.513	-0.904	1.191***	-4.746***	-3.214***
Wald (chi2)	5.0e+05***	1669.61***	1309.50***	7.2e+05***	4410.69***	5.8e+08***
Observations	366	366	366	366	366	366

Table A3 – Regression for *The productivity hypothesis* *(heiXX represent individual university controls)*

	Supervision of undergrad thesis	Supervision of master thesis	Supervision of PhD Thesis	Articles in peer review journals	Consultancy (gov. or firms)	Prototypes and patents
Inbreeding	-0.003	-0.078	0.206	-0.189*	1.435***	0.933
Years since first contract	0.016	0.065	0.033	-0.018	0.051	-0.187
Years since first contract squared	-0.0003	-0.0010	-0.0002	0.0003	0.0004	0.005**
Male	0.024	0.310*	0.341	0.136	1.656***	1.286
Participate collective R&D project	0.229	0.845***	0.802**	0.452*	0.745	-0.595
Funding for R&D last 3 years	0.392	0.091	0.891***	0.212	-0.141	0.078
Teaches graduate students only	-0.653**	-0.560*	-0.429	-0.537***	1.333**	0.421
Teaches undergraduate students only	0.486	0.552**	0.882	0.123	1.817***	1.839
Average number of students per class	0.0141**	0.0007	-0.0104	0.0002	0.0043	-0.002
Engineering and technology	0.463*	0.0362	-0.818**	-0.457**	2.729***	-1.125
Educational and Human sciences	-0.106	-0.116	-0.099	-0.330	1.722*	0.792
Social sciences and administration	0.569**	-0.194	0.036	-0.205	2.224***	-2.565
Natural and exact sciences	0.178	-0.449**	-0.399	-0.118	1.636**	0.296
Constant	-0.445	-1.243**	-2.096***	0.988***	-7.466***	-2.300
Wald (chi2)	21.19*	56.53***	49.30***	34.55***	75.22***	15.35
Observations	142	142	142	142	142	142

Table A4 – Regression for *The research oriented university effect hypothesis* (UNAM analysis)