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Essays in Higher Education: Internationalization, Competition, Funding mechanisms

Doctoral Dissertation

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Science can purify religion from error and superstition; religion can purify science from idolatry and false absolutes. Each can draw the other into a wider world, a world in which both can flourish.

(Pope John Paul II, 1988)

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CHAPTER 1. Introduction

Universities as institutions have their origin in the Medieval Christian setting, as the Church was the only institution in Europe that showed consistent interest in the preservation and promotion of knowledge. Churches indeed acted as both the guarantor of academic freedom and arbitrator of its boundaries. Across time, the University and the Church have undergone different growth paths, which lead academic institutions to continuously revisit their mission to society. In the Middle Ages, universities were a rule-governed community of scholars, served as repositories of knowledge and wisdom, where their main goals were the preservation and transfer of existing knowledge. Only in the eighteenth century, universities embraced the teaching mission, educating civil servants who would fill the administrative ranks of the newly formed European states. Thereafter, in the middle of the nineteenth century, universities started to focus on scientific research through rational inquiry and experimentation, becoming centres of scientific knowledge into the society. Further, during the last decades universities started to deal with other set of activities in addition to teaching and research, those related to regional development and economic engagement.

The evolution of universities' missions demonstrates how academic institutions have survived by turning institutional confusion and crisis into re-examination, search and innovation (Olsen 2007). The context of the great changes we are undergoing can be an important opportunity to re-think once again the role of university. To this extent, the purpose of this research is to shed light on the different dynamics that modify the activity of universities and researchers in the last decades. In particular, the work focuses on three different topics: the internationalization of universities, the competition for students they have been subjected to and the funding mechanisms fostering PhD students' research performance during and after the doctoral program.

The first paper investigates whether the internationalization of universities might affect the contribution of universities to the growth of firms. Today, universities promote and engender broad internationalization into their core missions to be or remain competitive, thus attracting more international resources and increasing their international prestige. Drawing upon this consideration, we argue that the larger and diversified networks of more internationalized universities are expected to be beneficial to firms affiliated with academic institutions since these academic institutions may act as a conduit

enabling them to access knowledge from the "global pipelines" of international academic research networks (OECD, 1999). As far as international networks provide access to a larger extent of innovation, knowledge and resources, the first paper of this thesis investigates whether the affiliation with more internationalized universities, which have access to more valuable resources, make affiliated firms more attractive in the eyes of international acquirers. To test whether the firm's affiliation with an internationalized university increases its attractiveness the work considers a unique dataset of biotechnology firms that went public in Europe over the period 1990-2006. The rationale for using a dataset of biotechnology companies is the enhanced capacity of these firms to absorb universities' externalities, while the choice to consider firms that have been commercially successful enough to make an IPO is motivated by the fact that firms must be successful or at least transparent to gain the attention of external acquirers

The second paper presented in this thesis aims to analyze the competition forces developed among universities for attracting more students, and consequently more tuition fees, as a reaction to the government funding cuts for the higher education systems occurred in the last years in Southern European countries (EUA 2013; 2014). Collecting financial resources has indeed become a priority for universities to ensure the pursuit of their daily core activities and long-term survivability (Wangenge-Ouma and Langa 2010; Christopherson et al. 2014). The fiercely competitive environment that has consequently emerged among universities has led them to increase their focus on the determinants of attractiveness to students, affecting their educational offer and the way they provide services to their stakeholders. Relying on the population of Italian universities, the third chapter examines the impact of competition forces on the student attraction to Italian universities and the evolution of competition dynamics during the period 2002-2012, with a specific focus on the effects of the ongoing financial crisis.

Third, the last paper of the thesis focuses on a specific typology of funding mechanisms that of financially supporting PhD students during their doctoral program. In particular, the work investigates how different doctoral funding resources might affect the research performance of PhD holders during and after their doctoral program. On the one side, this study is motivated by the fact that the recent financial crisis in Europe (and in other parts of the world) has led to important cuts on doctorates' financial support, ignoring the negative effects these policies may have in the middle-long run. On the other

side, there is a lack of understanding in the literature on how doctoral funding affects research performance. Specifically, this work examines whether PhD funding sources affect research productivity and visibility (as measured by citations) during the PhD and throughout the researchers' careers. The analysis draws on a representative sample of researchers holding PhDs resident in Portugal in 2009 using data obtained through a survey designed and implemented by the statistics office of the Ministry of Science and Education for the OECD Careers of Doctorate Holders project.

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CHAPTER 2. Cross-border M&As of biotech firms affiliated with internationalized universities

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Abstract

This paper provides a conceptual and empirical account of the role of the firms' affiliation with universities in the international market for assets. We investigate whether the prestige and the internationalization of a university affect the propensity of affiliated spin-offs to be targeted in cross-border M&As. This is because the affiliation with a prestigious university is expected to increase the technological capabilities and network opportunities of affiliated firms and to provide a more dynamic and mobile human capital. Moreover, in high tech markets the reputation of the affiliated university helps overcoming information asymmetry on the quality of the firm and its market value. Using a sample of 220 biotech firms that went public in Europe over the period 1995-2006, we find that firms affiliated with more prestigious and internationalized universities are more prone to be targeted in cross-border M&As. Results are robust to different methodologies, definitions and endogeneity of prestige and internationalization.

Key words: Academic entrepreneurship; Spin-offs; IPOs; M&As; Internationalization.

Paper co-authored with Michele Meoli, University of Bergamo; Silvio Vismara, University of Bergamo.

1. Introduction

No single firm possesses all the resources and capabilities in house to innovate and success. This is particularly true in the biotechnology industry, where knowledge flows, and especially their tacit components, are bounded by location (Schmidt and Sofka 2009). Among the different alternatives to access critical and valuable resources in the international context, foreign direct investment, and cross-border M&As in particular, are among the most effective ways (Chung and Alcácer 2002). In this regard, research-based spinoffs might be the ideal targets for international acquirers, because of their direct involvement in developing radically innovative technologies. Their relevance at a national level is also proved by the central role they play in innovation policies (Audretsch et al. 2012) and the continuous series of measures adopted to encourage their formation and development (Mustar and Wright 2009).

This study develops and empirically tests a framework that links the benefits arising from the affiliation with a university to the interest of international acquirers for university-affiliated firms. Recent literature has shown that the affiliation with a university is recognized by external investors who are willing to pay more for taking an equity position in these firms (Bonardo et al. 2011; Meoli et al. 2013). We investigate whether the prestige and the internationalization of a university affect the propensity of affiliated firms to be targeted in cross-border M&As. The affiliation with a prestigious university is indeed expected to increase the value-adding benefits associated with an "ordinary" affiliation, both in terms of technological capabilities and network opportunities (Wang and Shapira 2012). Internationalized universities provide affiliated firms with a more dynamic and mobile human capital (Edler et al. 2011). Similarly to target firms that operate in different countries, these firms have access to foreign external networks, which can be highly valued by international acquirers.

We explore these issues using the population of 220 biotechnology firms that went public in Europe in the period 1990-2006. The IPO market represents a favorable setting where the "uncertainty-reducing" endorsement by prestigious third parties strongly helps overcoming information asymmetry on the quality of the firm and its market value. Moreover, the IPO creates publicly priced shares to be used as currency to participate in M&As. Divesting after a company has been made public is often a better strategy than

selling a still private firm directly at a value that is lower due to illiquidity discount (Bonardo et al. 2010). Such advantages of sequential divestures through IPOs are especially high in knowledge-intensive industries. In this framework, we specifically investigate the effects of the (1) affiliation with a university, (2) the affiliation with a prestigious university, and (3) the affiliation with an internationalized university. The dependent variable is the probability of affiliated firms to be targeted in cross-border M&As.

Out of 220 biotech IPOs in Europe, we find that 74 firms were targeted within five years in M&A deals by foreign acquirers. This propensity to be acquired is particularly marked for firms affiliated with more prestigious and more internationalized universities. This evidence is confirmed by the results of probit regressions, controlling for endogeneity between internationalization and prestige of universities. Independently from the level of prestige of the parent university, firms affiliated with more internationalized universities attract more interest from foreign investors. The ongoing process of internationalization of universities is therefore expected to lead to more international academic entrepreneurship. Ultimately, regions with internationalized academic institutions will be more equipped to face global challenges.

This paper is organized as follow. Section 2 is dedicated to the development of the testable hypotheses. Section 3 describes the research design and Section 4 shows the results. Section 5 concludes.

2. Testable hypotheses

This paper investigates whether the probability of a firm to be targeted in cross-border M&As is enhanced by: (1) the affiliation with a university, (2) the affiliation with a more prestigious university, (3) the affiliation with a more internationalized university.

2.1 Affiliation with a university

Meoli et al. (2013) show that the affiliation with a university enhances the valuation of the firms and the probability of being targeted in M&As. The acquisition of these firms provides indeed academic founders with an exit opportunity that allows them to return to

their original scientific activities. Takeovers are therefore effective in establishing new management structures in science-based firms. On the other side, they are also helpful in bringing the innovative capabilities of the smaller firms to the larger acquiring firms, that are better equipped to exploit such innovations, thanks to complementary assets (Lehmann at el., 2012).

If the affiliation with a university enhances the probability of being targeted in M&As, this is expected to be particularly true for cross-border M&As. When a foreign firm enters in a local market generally suffers from the "liability of foreignness" (Zaheer 1995), namely the unfamiliarity with the target country's culture, language, business practices and regulations. Different ways to alleviate acquirers' difficulties in entering and establishing in a new country have already been identified, such as contractual remedies (Reuer et al. 2004) or joint ventures (Reuer and Koza 2000). We offer a new perspective arguing that foreign firms can ameliorate this liability by acquiring university-affiliated firms. The endorsement of prominent players in the host country, including universities, can reduce the risk of insulation. This implies that firms affiliated with universities are more attractive targets for foreign acquirers.

The reverse-internalization theory is of help in explaining the value of a university affiliation in an international context. The increasing trend of R&D internationalization requires companies to select critical resources across borders in order to take directly advantage of localized excellence around the world. Today's globalized markets have also led firms to fragment geographically different their activities, as production processes, implying an increasing international division of labour (Audretsch et al. 2014). The privileged scientific and technological resources of firms affiliated with universities make them attractive targets. The value-added benefits of this affiliation include also the availability of knowledge and physical resources, such as libraries and laboratories, and the improvement of R&D flexibility through the on-going contact with emerging technologies and through absorption of "knowledge spillovers" (Audretsch and Lehmann 2006).

Based on these arguments, we expect university affiliation to increase the attractiveness of a firm for international investors, and therefore increase the probability of being targeted in a cross-border M&A.

Hypothesis 1: *The affiliation with a university increases the probability to be targeted in cross-border M&As.*

2.2 Affiliation with a prestigious university

While the presence of information asymmetries may hinder potential investors to evaluate the technology and the innovation of firms, a higher university's reputation may help investors to consider that the technology of its affiliated firms is scientifically legitimate. More prestigious universities may naturally increase the international visibility of their affiliated firms, giving access to their international relationships and visibility.

If the affiliation with a university is a signal that a firm has access to specific resources and contacts, this signal can be stronger for more eminent universities. The affiliation with a prestigious university is expected to increase the benefits of "ordinary" affiliations, because it provides connection to more qualified resources. Prominent universities are indeed expected to possess the best faculties, instruments, equipment, and to provide high quality research that may result in leading-edge innovations (Wang and Shapira 2012).

Finally, drawing from economic sociology (Podolny 1993), the imperfections in the knowledge markets imply that knowledge transfer may depend more on the status or prestige of an institution rather than on the type of services and goods provided. Consequently, when information asymmetries make it difficult for investors to value a technology, they often rely on status or prestige of the institution spawning the venture (Sine et al. 2003). Therefore, potential acquirers and investors suppose that firms affiliated with more prestigious universities produce technology that is more worthy of funding. The role of status is more important when the information problems are higher, such as in the case of M&As pursued by foreign firms.

The implication of these arguments is that, *ceteris paribus*, the affiliation with more prestigious universities is expected to increase the probability to be targeted in cross-border M&A deals.

Hypothesis 2: *The affiliation with a more prestigious university increases the probability to be targeted in cross-border M&As.*

2.3 Affiliation with an internationalized university

The internationalization of universities has become a world-wide phenomenon as global economic integration makes its way into higher education. This issue has risen to the top of the agenda of governments, as well as in world-class universities. In order to be or remain competitive, universities promote and engender broad internationalization into their core missions. The larger and diversified networks of more international universities are expected to be beneficial to affiliated firms since universities may act as a conduit enabling them to access knowledge from the "global pipelines" of international academic research networks (OECD, 1999). As far as innovation lies within a network of firms and research institutions, rather than within the boundaries of individual firms (Powell et al. 1996), international networks provide access to a larger extent of knowledge and resources. We therefore argue that firms affiliated with more internationalized universities have access to more valuable resources, which make them more attractive in the eyes of international acquirers.

At an individual level, people working in different environments are more likely to possess original ideas, different viewpoints and creativity (Fleming et al. 2007). This is a key aspect for research. Scientists and professors of more international universities have more frequent opportunities of exposure to different cultures, business practices and institutional frameworks. The higher possibilities to be involved in external contexts enrich their technical and cultural know-how because of intense contact with heterogeneous collaborators and resources (Edler et al. 2011).

We argue that the higher scientists' international opportunities granted by more internationalized universities can enhance the boundary-spanner role of researchers and contribute to transfer higher valuable expertise to their affiliated firms. Their mobility enriches the flow of knowledge, cognitive integration, and provides international incumbent firms with higher access to knowledge through their own researches, but also by being part of a broader scientific community.

Firms affiliated with internationalized universities can additionally benefit from the opportunity to employ more dynamic and opened-minded human resources which may foster their competitive advantages. The integration between international and local

students indeed allows to train students with improved ability to work in team and fewer difficulties in interacting with foreign cultures.
We therefore hypothesize that the affiliation with more internationalized universities leads to higher probability to be targeted in cross-border M&As.

Hypothesis 3: *The affiliation with a more internationalized university increases the probability to be targeted in cross-border M&As.*

3. Research design

This work investigates at a firm level whether the (1) affiliation with a university, (2) the affiliation with a prestigious university, and (3) the affiliation with an internationalized university have a positive impact on the probability of being targeted in a cross-border M&A. To test our set of hypotheses, we consider a unique dataset of biotechnology firms that went public in Europe over the period 1990-2006. The rationale for using a dataset of biotechnology companies is the enhanced capacity of these firms to absorb universities' externalities. The choice to consider firms that have been commercially successful enough to make an IPO is motivated by the fact that firms must be successful or at least transparent to gain the attention of external acquirers (Paleari and Vismara, 2007). Indeed, because of the concrete difficulties for bidders to evaluate the potential of biotechnology firms, M&A negotiations tend to be lengthier and buyers often respond by offering lower bids. The high level of uncertainty associated with knowledge-intensive firms indeed makes the valuation difficult for acquirers. For these reasons, a sequential divestiture strategy using an IPO can be attractive for founders, as it increases the level of their firm's disclosure and raise the firm's profile (Shen and Reuer 2005). The intense ties between scientific and financial capital in this industry is also testified by the large number of IPOs of firms affiliated with universities. In Europe, 40% of the IPOs of university-based firms in the period 1995-2003 were in the biotech sector (Bonardo et al. 2011).

The initial list of companies is from the EURIPO database[1]. We rely on the Thomson Financial Securities database, cross-checked using Zephyr, to identify the M&A deals involving the sample firms up to December 2011. We collect a total number of 322 deals where our sample firms were targeted, of which 122 were cross-border deals. One third of the sample firms (74 firms) were involved in at least one cross-border deal as target[2].

3.1 Affiliation with a university

We rely on the information in the offering prospectus to determine a firm's university affiliation. This document is the primary tool for companies to communicate information to potential investors at the IPO stage. Companies going public are indeed required to describe their history and to report the curriculum vitae of their board members and top managers (upper echelons). Referring to these two specific sections of the IPO prospectus, we distinguish between university-affiliated and non-university-affiliated firms identifying the former as those companies that were either developed by faculty members based on their own research or created specifically to capitalize on academic research (O'Shea et al. 2008; Bonardo et al. 2011)[3]. Examples taken from IPO prospectuses are as follow:

[1] "Oxford Asymmetry was originally founded to commercialise the chiral chemistry technology and expertise practised by the Company's scientific founder, Professor XX of the University of Oxford."

[1] See Vismara et al. (2012) for a description of this database. Consistent with the definitions provided by Audretsch (2001), we identify biotech firms considering code 4573 of the Industry Classification Benchmark (ICB), which is composed by Healthcare (45), Pharmaceuticals & Biotechnology (7), and Biotechnology (3). The ICB is the official industry classification adopted by the European stock exchanges.
[2] Data on acquisitions include deals identified by the cut-off ownership levels for mandatory disclosures required by national laws, and deals where both the acquirer's and the target's country are known. All double-counting transactions are excluded. In all of the jurisdictions considered, there was a formal obligation requiring major shareholders to disclose their holdings in a company.
[3] Since the purpose of the prospectus is to sell shares, it is assumed that all relevant information will be included. Moreover, since owners and managers are legally accountable for errors in the document, it contains the most accurate information available. As a result, prospectus data are considered reliable and enjoy a longstanding role in strategy and entrepreneurship research (Shrader and Siegel 2007).

[2] "The GENEART Ltd., whose business continues as GENEART AG, was founded in 1999 as part of a spin-off of the University of Regensburg, founded by Prof. Dr. XX, Dr. XX and Prof. Dr. XX". (Translated from German)

[3] "WILEX is a biopharmaceutical company based in Munich and established in September 1997 by a team of physicians and oncologists from the Technical University of Munich, among others, Dr. XX, Prof. Dr. XX and Prof. XX" (Translated from German)

Table 1 describes the sample by country, IPO year and firm size. At the time of the IPO, 24% (53) of the full sample is composed by firms affiliated with a university. UK is the most represented country with 105 (48%) IPOs, while Germany and France are represented by 37 and 39 IPOs, respectively. Other countries with at least three companies in the sample include Italy, Belgium, the Netherlands and Sweden. The French sample includes only 4 university-affiliated firms over the full period considered, as compared to 34 affiliated firms in UK and 12 in Germany. Most of the companies went public between 2000 and 2006. The pre-IPO net sales of most of the firms were lower than 20 €m, in particular for those affiliated with universities.

Table 1. Sample

	IPOs (No.)	University affiliated firms (No.)
Country		
UK	105	34
France	39	4
Germany	37	12
Other countries	39	3
IPO year		
1990s	57	12
2000-2003	69	19
2004-2006	94	22
*IPO size (€m)**		
Size <=1	63	18
1<Size<=5	54	17
5<Size<=20	60	15
Size > 20	43	3
Total	*220*	*53*

* Size is measured as net sales in the year prior to the IPO, adjusted for inflation (2006 purchasing power)

3.2 Affiliation with a prestigious university

The impact of university prestige is usually measured by considering world university rankings (e.g. Sine et al. 2003). The literature debates about the interpretation of university ranking measures arguing that they are indicators of reputation rather than of quality, although rankings themselves have become an important part of reputation (Bowman and Bastedo 2011).

In this paper, the prestige of universities is measured using the ARWU (Academic Ranking of World Universities), a yearly publication of the Jiao Tong University in Shanghai since 2003. We rely on this indicator because of its assumed superiority as a measure of university excellence (Taylor and Braddock 2007). This ranking is indeed credited to offer a more objective indicator of research outputs compared to the higher subjectivity of alternative international rankings based on both peer reviews and reputational indicators (Saisana et al. 2011). In our analysis, we therefore use the median value of the ARWU ranking for the university-affiliated firms in the period 2003-2011. Each university has been scored a value equal to $(\text{median ranking})^{-1}$, so that the maximum score is 1 for the University of Harvard, that ranks first in the ARWU from 2003 to 2011. In the robustness section, we use an alternative raking, namely the one provided by the THES (Times Higher Education Supplement).

3.3 Affiliation with an internationalized university

The multi-dimensional structure of academic institutions makes it complex to measure their degree of internationalization. A university can specialize and pursue the excellence into different specific functions. We differentiate the measure of internationalization according to the three missions of universities: teaching, research and the so-called "third mission".

First, we consider the percentage of international students to proxy the internationalization of universities in education. The growth in number of international students has been identified as a significant part in the internationalization process of academic institutions (Knight and de Wit 1997). The university staff involved in this process has to model its teaching program in an international perspective introducing

effective communication strategies to allow the integration of international students. Therefore, the higher is the proportion of international students in a university, the greater its teaching programs are modeled in an international way. We collect information from the Facts and Figures document of each university with at least an affiliated firm in our sample.

Second, international co-authored publications are used to measure the internationalization of scientific research. Scientists generally communicate and collaborate to transfer knowledge co-authoring their scientific outputs. Prior research considers co-authored publications as a proxy of collaborative R&D (e.g. Wang and Shapira 2012). International publications are identified when they are co-authored at least by two authors from different countries in the SciVerse Scopus database.

Third, we consider the percentage of international patents as a proxy of the university's internationalization in the third mission. University co-patenting is a mechanism in which academic institutions collaborate and exchange technological knowledge with other public research institutes and industrial companies, through the co-authorship of different inventors (Van Looy et al. 2003). Following prior research, we use international co-patenting as a proxy of the international R&D collaborations of enterprises (Yamin and Otto 2004). This variable is measured relying on co-patenting data in the SciVerse Scopus database[4].

Table 2 reports the statistics, as well as the list of affiliated companies, of the 15 most prestigious universities with at least one affiliated company in our sample. The most prestigious universities are Harvard, Stanford, Cambridge, and Oxford. Oxford is the university with the largest number of affiliated IPOs (7). To control for the specificities of major US universities[5] in a sample of European affiliated firms, we include a dummy variable for US universities in all our regressions.

[4] Since our purpose is to measure university's international collaborations in science, and being biotechnology not a separate field but rather a mix of disciplines transmuted into productive processes, we consider also patents in scientific areas such as chemical engineering, information technology, and robotics. Our results are consistent when we consider a tighter definition of biotechnology to filter university patents.

[5] Cassia et al. (2014), i.e., highlight how knowledge transfer activities are more developed in US entrepreneurship research centres than in in the equivalent EU structures.

Table 2. The 15 most prestigious universities with at least a firm affiliated in the sample.
University prestige is measured using the ARWU (Academic Ranking of World Universities) ranking and the THES (Times Higher Education Supplement) ranking. University internationalization is measured considering the percentage of international students (teaching), publications (research) and patents (third mission). We report rankings and internationalization measures at 2011.

University	Country	Prestige		Internationalization			Affiliated firms	IPO
		ARWU	THES	Teaching	Research	Third Mission		year
Harvard University	US	1	2	20.00	43.23	22.58	Weston Medical Group	2000
Stanford University	US	2	2	21.00	37.89	18.64	Transgene	2001
University of Cambridge	UK	5	6	20.30	59.95	75.94	Alyzime	2003
							Abcam	2005
							Bioproject International	2002
University of Oxford	UK	10	4	38.10	60.14	42.04	Oxford Molecular	1994
							Oxford Biomedica	1996
							Powderject Pharmaceuticals	1997
							Oxford Asymmetry International	1998
							Oxford Glycosciences	1998
							Premier Research Group	2004
							Oxford Catalyst	2006
University of California, San Diego	US	15	33	6.69	37.70	17.75	Macropore Biosurgery	2000
Johns Hopkins University	US	18	14	11.20	39.44	23.08	Cardiomag Imaging	2005
University College London	UK	20	17	39.86	43.45	78.32	Ark Therapeutics Group	2004
University of Manchester	UK	38	48	18.50	51.27	30.00	Cyprotex	2002
							Neutec Pharma	2002
University of Edinburgh	UK	53	36	27.32	56.22	22.22	Stem Cell Sciences	2005
Technical University Munich	Germany	54	88	17.00	50.68	26.67	Pulsion Medical System	2001
							Wilex AG	2006
University of Munich (Ludwig Maximilians)	Germany	54	45	14.13	51.79	50.00	Medigene	2000
University of Heidelberg	Germany	62	73	17.37	52.53	50.00	Lion Bioscience	2000
							Co.Don	2001
King's College London	UK	68	56	33.32	50.33	64.44	Lidco Group	2001
							Proximagen Neuroscience	2005
Ecole Normale Superieure, Paris	France	69	59	11.11	56.22	25.00	Cerep	1998
University of Sheffield	UK	97	101	26.12	48.75	25.00	Biofusion	2005
							Prostrakan	2005

3.4 Control variables

The interest of international acquirers is not only related to the university affiliation, but could emerge from other firms' peculiarities. Our analysis includes specific controls, all measured at the time of the IPO and grouped into three categories: (1) general characteristics of the firm, (2) innovation, and (3) upper echelons.

Table 3 provides the detailed definitions of all the variables.

Table 3. Definitions of variables

All variables were measured at the time of the IPO. In the regressions, the sales, age (years + 1), patents, and upper echelon size are expressed as natural logarithms.

FIRM VARIABLES	
Dependent Variable	
Cross-border deals as target	Dummy variable equal to 1 for companies targeted in at least one cross-border M&A within 5 years after the IPO
Affiliation	
University-affiliated firms	Dummy variable equal to 1 for companies affiliated with a university
Firm and offer characteristics	
Firm size (€m)	Sales. Inflation is adjusted through local GDP deflator (source: Datastream)
Age (years)	Years since incorporation
Growth rate (%)	Compounded annual growth rate of return on assets for the period t and t-3, where t is the IPO year (Cogliati et al., 2011)
VC backed	Dummy variable controlling for the presence of at least one venture capital at the time of IPO
Top-ranked Underwriter	Dummy variable controlling for the participation of a prestigious underwriter at the IPO. Prestigious underwriters are defined as in Migliorati and Vismara (2014)
Biotechnology cluster	Dummy variable equal to 1 for firms located within one of the eleven European biotech clusters, as reported in Table 4
Selection instrument	
Prone to IPO	Selectivity instrument created through Heckman procedure to control for the propensity to go public (Pollock et al. 2010; Meoli et al., 2013)
Innovation	
R&D investments (%)	Ratio between R&D investments and assets, prior to the IPO (Vismara, 2013)
Patents (No.)	Number of patents held
Upper echelon	
UE with PhD (%)	Proportion of upper echelons (board members and top managers) that are professors or hold a PhD degree
UE with MBA (%)	Proportion of upper echelons with an MBA degree
UE international experience (%)	Proportion of upper echelons who had prior international experience attained in an international division, abroad on assignment, and/or in higher education
UE industry experience (%)	Proportion of upper echelons who had prior experience in biotechnological or pharmaceutical companies
UE size (No.)	Number of board members and top managers (upper echelons)

	UNIVERSITY VARIABLES
University prestige	
	The ARWU (Academic Ranking of World Universities) ranking is based on worldwide university ranking published by the Jiao Tong University in Shanghai. We associate to the university-affiliated IPOs the median value in the period 2003-2011 of the tied university. Each university has been scored as (median ranking)$^{-1}$
University internationalization	
Teaching	The percentage of international students. We consider the Facts and Figures document of each university. Percentages are associated to the university-affiliated IPOs of the tied university
Research	The percentage of international co-authored publications in the biotech area for each university (source: SciVerse Scopus database). A publication is international if at least two of the scientists are from different countries. We associate to the university-affiliated IPOs the average percentage of international publications of the tied university in the period 2001-2011
Third Mission	The percentage of international co-authored patents for each university (source: SciVerse Scopus database). We follow the "inventor criterion": a patent is international if at least two of the inventors are from different countries. This indeed implies that one inventor and one applicant are from different countries. We associate to the university-affiliated IPOs the average percentage of international patents of the tied university in the period 2001-2011
US university	Dummy variable equal to 1 for US universities

To isolate the "reputational" effect of university affiliation, we control for the quality of target firms and the context of the acquisition. The first set of control variables considers firms' general characteristics (e.g. size, age) and dummy variables for countries and years. We also include the growth rate of profitability in the three years prior to the IPO, as a measure of firm quality (Bayar and Chemmanur, 2012). Since a peculiarity of biotechnology firms is to be often located in geographically bounded clusters (Chiaroni and Chiesa, 2006), we also include a dummy variable to control for firms belong to one of the 11 European biotechnology clusters, identified as in Cooke (2001) and Chiaroni and Chiesa (2006)[1]. Table 4 reports the list of European biotechnology clusters, and their number of IPOs and of university-affiliated firms in our sample. We find that 70 IPOs (32%) are located in one of these clusters, and only 17 firms of them are affiliated with a university. The most represented clusters are Surrey (22 firms), Cambridge (16 firms), Paris-Evry (13 firms) and Oxford (12 firms).

Table 4. European biotechnology clusters

Clusters are identified as in Cooke (2001) and Chiaroni and Chiesa (2006). IPOs-firms belong to a cluster when they are located within 50 km from its centre.

Cluster	Number of IPOs	University-affiliated firms
Aarhus	0	0
Biovalley	1	0
Cambridge	16	5
Heidelberg	1	1
Marseilles	0	0
Milan	4	0
Oxford	12	4
Paris-Evry	13	1
Scotland	1	0
Surrey	22	6
Uppsala	0	0
Total	70	17

[1] Firms belong to a cluster when they are located within 50 km from its centre, with the exception of the following clusters, where we consider the specific radius (km) reported in Chiaroni and Chiesa (2006): Cambridge (30), Heidelberg (40), Marseilles (30) and Milan (30). For the Biovalley cluster (Upper Rhine Valley), the city of Basel is the centre. A firm belongs to the Scot cluster if located within the triangle of Dundee, Edinburgh and Glasgow, or within 10 km from one of these cities.

The second set of controls measures the level of innovation with two different variables: the level of R&D investments, as a measure of input and the number of patents[2], as a measure of output. As university-based firms generally have scarce initial resources, the human capital of their founders is one of their main business assets (Criaco et al., 2013). Coherently, the third set of variables considers a number of measures to exhaustively evaluate the qualities of the upper echelons (UE)[3]: the percentage of directors with MBA or Ph.D. degrees, the percentage of the UE components who had a prior experience managing biotechnological or pharmaceutical companies, and the percentage of directors of the UE that had an international experience prior the IPO.

Additionally, we also include a selectivity instrument in all our regressions to control each firm's propensity to go public. The choice to consider only IPO firms may indeed introduce a "success" bias, which could influence our estimations. In line with prior research (e.g. Pollock et al. 2010; Meoli et al., 2013), we implement the Heckman[4] procedure to tackle this issue.

Correlations, means and standard deviations of the variables are presented in Table 5. Firms are on average 9 years old at the IPO, with 37 million euro in sales and a growth rate of profitability of 10% over the 3 years before the IPO. The portfolio of

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[2] We consider the number of patents on which the firm had exclusive rights at the date of the IPO, as published in the prospectus. Such measure captures not only patents issued directly to the firm, but also patents acquired through arrangements with other firms. When missing, the patent variable was completed by measuring the number of patents as reported by the US and by the European Patent Office issued to the firm up to the date of the IPO.

[3] The *upper echelon* consists of board members and top managers. The benefits of having prestigious members in both categories at the time of IPO registration are well known. Executives with lustrous credentials and experience may be more capable of leading a company through the IPO transition, and prestigious outside directors can reassure markets that the firm will be able to secure scarce resources. In the regression analysis, we controlled for the relational and educational capital of the upper echelon (advisory role) as well as board-independence and corporate governance mechanisms (agency role). Bertoni et al. (2014) show that the relative importance of the two roles varies over time, with advisory (agency) dominating in IPOs of young (mature) companies. Relying on the definition of upper echelons allows us to better account for differences in the design and functioning of top management teams across national borders.

[4] The Heckman procedure allows us to create a selectivity instrument. We initially extract from the Bureau van Dijk's Amadeus database a list of biotech firms that did not go public between 1990 and 2006. To match treatment units (IPO-firms) with control units (private firms), we first estimated the propensity scores, or fitted values, using the nearest-neighbor propensity scores. Then, we performed a logistic regression, where the predictive variables were firm size (revenues) and age (year of foundation) and country dummies. This regression was used to create the selectivity instrument that was included among the baseline regressors in our models.

patents counts on average 39 patents, with R&D investments accounting for 8.8% of their assets. Upper echelons are on average made of 9.4 members, with a higher number of directors with Ph.D degrees than with MBA degrees (22.4% vs. 16.7%). A fairly important number of directors had prior experience in the international context (42.7%) and/or in managing biotechnology or pharmaceutical companies (33.1%).

Table 5. Descriptive statistics and matrix correlation

In bold the significant values ($p < 0.01$).

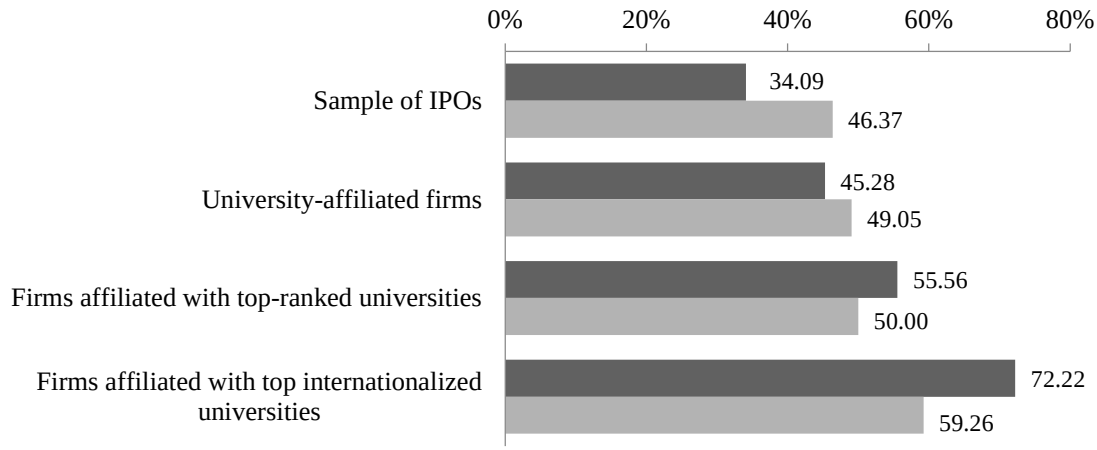
	Variables	Mean	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	Size (€m)	37.30	12.00	1.000																		
2	Age (years)	9.24	10.36	**0.350**	1.000																	
3	Growth rate (%)	20.66	103.13	**-0.244**	-0.109	1.000																
4	VC backed (%)	41.36	49.36	-0.155	-0.076	-0.034	1.000															
5	Top-ranked underwriter (%)	15.91	36.66	-0.037	0.017	-0.018	0.169	1.000														
6	R&D investments (%)	8.81	24.89	**-0.244**	-0.096	0.088	0.042	0.046	1.000													
7	Patents (no.)	38.64	112.84	0.038	0.009	-0.001	**0.206**	**0.242**	-0.134	1.000												
8	UE with PhD (%)	22.44	22.85	-0.136	-0.072	-0.064	0.141	0.115	0.029	0.135	1.000											
9	UE with MBA (%)	16.68	19.45	**-0.265**	-0.134	0.003	**0.325**	**0.216**	0.123	**0.184**	**0.341**	1.000										
10	UE international experience (%)	42.72	78.32	-0.100	-0.016	0.029	0.008	0.020	0.008	-0.066	**-0.177**	-0.048	1.000									
11	UE industry experience (%)	33.13	12.78	**-0.185**	**-0.203**	-0.016	**0.204**	0.112	0.027	0.083	**0.375**	**0.442**	-0.066	1.000								
12	UE size (no.)	9.44	4.44	0.045	-0.006	0.015	0.137	0.117	-0.031	0.058	**0.194**	0.124	-0.048	-0.166	1.000							
13	University-affiliated firms (%)	24.09	42.86	-0.100	-0.108	0.129	0.023	-0.040	-0.028	0.025	0.079	**0.198**	-0.043	**0.200**	0.016	1.000						
14	UNI_Prestige	0.01	0.03	-0.123	-0.090	**0.174**	0.063	0.049	-0.038	0.115	0.147	0.090	-0.060	0.025	0.084	**0.239**	1.000					
15	UNI_Teaching (%)	4.04	9.31	-0.088	**-0.184**	0.128	0.013	0.045	-0.001	0.045	0.101	0.168	0.007	0.128	0.095	**0.617**	**0.393**	1.000				
16	UNI_Research (%)	9.46	17.76	-0.094	-0.156	0.141	0.040	-0.012	-0.026	0.056	0.093	**0.222**	-0.022	**0.200**	0.005	**0.758**	**0.353**	**0.864**	1.000			
17	UNI_ Third Mission (%)	7.21	18.38	-0.087	-0.121	0.062	0.069	-0.059	-0.026	0.004	0.091	**0.199**	-0.040	**0.211**	0.052	**0.558**	**0.314**	**0.686**	**0.727**	1.000		
18	US university (%)	5.50	22.80	0.022	-0.049	0.106	0.002	-0.094	-0.002	0.067	0.072	0.047	-0.035	0.063	0.124	**0.341**	**0.227**	**0.176**	**0.274**	0.119	1.000	
19	Biotechnology cluster (%)	35.45	47.95	0.016	-0.109	-0.037	0.034	0.007	**0.184**	-0.061	0.056	0.090	-0.023	0.027	0.151	0.022	0.112	0.152	0.054	0.129	0.031	1.000

4. Results

Figure 1 represents the percentage of firms targeted in at least one cross-border or at least one domestic deal within 5 years after the IPO. We report this percentage for the full sample of IPOs and for three subsamples identified in accordance to our hypotheses: the university-affiliated firms, the firms affiliated with top-ranked[11] and top internationalized universities[12]. The percentage of firms that took part in an international acquisition as target is higher for university-affiliated firms (45%) than for the full sample (34%), and increases for firms affiliated with the top-ranked universities (56%) and, even more, with the top internationalized ones (72%). Almost half (46%) of our IPO are targeted in at least one domestic M&A within five years from the IPO. This percentage is slightly higher for university-based IPOs (49%). However, the impact of the affiliation does not seem to be as evident on domestic M&As as it seems on cross-border deals. These results are econometrically validated through probit regressions.

Figure 1. Percentage of firms targeted in cross-border and domestic M&As

This figure plots the percentage of firms that have been targeted in at least one cross-border (black bars) and domestic (grey bars) M&A within five years from the IPO in the full sample, in the subsample of university-affiliated firms, in a subsample of firms affiliated with the top-ranked universities (top15 ranked universities that have at least one affiliated firm in our sample, according to the ARWU), and in a subsample of firms affiliated with top internationalized universities (top15 universities that have at least one affiliated firm in our sample, in terms of % of international co-authored patents).



[11] Top-ranked universities are here defined as the universities included in the top 15 positions of the ARWU ranking.

[12] Top-internationalized universities are here defined as the 15 universities with the highest percentages of international co-authored patents.

Model 1 in Table 6 reports our baseline regression, including the factors influencing the attractiveness of the target firms in the eyes of international acquirers. Our proxy of firm quality (growth rate) is significant, confirming for cross-border deals that higher quality firms are more likely to be targeted after the IPO (Bayar and Chemmanur, 2012). Firm with a larger proportion of the upper echelons with a prior international are also more likely to be targeted in cross-border M&As. This can be due to their expected ability to smooth the difficulties of integration in the day-to-day post-acquisition activity, or it can also be the result of a more internationally-oriented exit strategy of the target itself. The presence of a VC is also slightly significant. Given the interest of venture capitalists in capitalizing their investment, this reinforces the idea that selling to a large company was an option actively pursued by the firm from the time of the IPO.

Models 2-6 in Table 6 show the results for our set of hypotheses. The first hypothesis is tested by examining the impact of the affiliation with a university on the probability of being targeted in cross-border M&As. We find that the university affiliation is significantly associated with a higher probability to be involved in a cross-border M&A as target (Table 6, Model 2). In accordance to our second hypothesis, university-affiliated firms are more attractive in the eyes of international acquirers when they are affiliated with a more prestigious university (Table 6, Model 3). The third hypothesis is tested by including our measures for university internationalization: the percentage of international students, international co-authored publications and international co-authored patents. We find statistical evidence that university-affiliated firms are more prone to participate in cross-border deals as targets when they are affiliated with more internationalized universities (Table 6, Models 4, 5 and 6). Specifically, the coefficient related to the university's international co-authored patents is strongly significant, highlighting that foreign collaborations in technology boost the interest of international acquirers. In these regressions, where we control for both the prestige and the internationalization of universities, the affiliation itself is not statistically significant, although still positive. This suggests that a "generic" university affiliation is not enough, and that only firms affiliated with prestigious and internationalized universities make available resources and services that attract foreign investors. Acquirers may also consider the acquisition of firms affiliated to prestigious and internationalized university a valuable strategy to facilitate their access into the local market by smoothing existing cultural barriers in different countries.

The last two columns of Table 6 corroborate the liability of foreignness phenomenon. First, at the time of the IPO because the "public" may not be specifically informed about

"quality" of the firm and may give importance to other value signals such as the prestige of the parent university. However, this mechanism is expected to be less true in the case of acquisitions by large companies, as the latter are supposed to have all the capabilities to assess the actual quality of the target firm. In such cases, the liability of foreignness would be reduced, as compared to when the acquirer is a smaller firm. Therefore, the legitimation effect associated with the affiliation with a university is expected to be more relevant for non-incumbents' acquisitions. To test for this effect, we run the same regression as in Model 6, but we exclude the acquisitions undertaken by incumbents, identified as those companies in the top decile among acquirers, for total assets. In this way, our dependent variable is equal to 1 only when the IPO-firm is targeted within five years, not considering acquisitions by incumbents. Our results confirm that the affiliation with a prestigious and internationalized university is even more important, as the magnitude of the coefficient of internationalization increases.

Second, we hypothesize that the benefits arising from the affiliation with a prestigious and internationalized university is more valuable in cross-border than in domestic acquisitions, because of the liability of foreignness. We therefore perform a probit regression on the probability of being targeted in a domestic M&A (Table 6, Model 8) and find the affiliation with a prestigious university to be less significant for domestic M&As. Furthermore, the international experience of the upper echelons is no longer significant in the case of domestic M&As, while the educational capital, proxied by the proportion of the upper echelons with a Ph.D degree, is associated to a higher probability of being targeted.

As a final aside, we note that the certification provided by prestigious underwriters makes the IPO more appealing for international bidders when we measure the internationalization of the parent university as teaching (Model 4) and when we exclude acquisition from incumbents (Model 7). It seems, therefore, that the certification of prestigious underwriters complements the signal associated to the internationalization of the university, in terms of teaching, while it might be overlapping when associated to the internationalization of the research and third missions of the universities. In addition, the affiliation with a prestigious underwriter is less relevant when the acquirer is an incumbent, probably due to its higher abilities to discern the quality of the firm and of the potential asset complementarities.

Table 6. Models (1-6) are probit regressions on the probability of being the target in a cross-border M&A. Models (4), (5) and (6) consider three alternative measures of university internationalization, related to Teaching, Research and the Third Mission. Model (7) is a probit regression on the probability of being the target in a cross-border M&A excluding those where the acquirer is an incumbent. Model (8) is a probit regression on the probability of being the target in a domestic M&A. Country and year dummies are included in all models. Robust standard errors are in parentheses. Significance level of 1% (***), 5% (**), and 10% (*).

				Teaching	Research	Third Mission	Excluding Incumbents	Domestic M&A
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Firm size	0.020	0.024	0.032	0.031	0.054**	0.031	0.022	0.042**
	(0.020)	(0.019)	(0.020)	(0.020)	(0.023)	(0.020)	(0.021)	(0.018)
Age	-0.084	-0.074	-0.104	-0.032	-0.193	-0.075	-0.105	-0.249
	(0.189)	(0.178)	(0.178)	(0.181)	(0.192)	(0.180)	(0.183)	(0.174)
Growth rate	0.667***	0.496**	0.497**	0.482**	0.450**	0.545**	0.498**	0.515**
	(0.225)	(0.213)	(0.209)	(0.198)	(0.210)	(0.213)	(0.198)	(0.222)
VC backed	0.320*	0.279	0.260	0.332*	0.057	0.232	0.075	-0.087
	(0.193)	(0.189)	(0.190)	(0.198)	(0.207)	(0.190)	(0.192)	(0.185)
Top-ranked underwriter	0.238	0.302	0.269	0.404**	0.156	0.347*	0.440**	0.218
	(0.196)	(0.190)	(0.190)	(0.189)	(0.208)	(0.193)	(0.195)	(0.195)
Prone to IPO	-2.071*	-1.463	-1.635	-0.662	-1.644	-1.526	-1.715	-1.051
	(1.195)	(1.132)	(1.148)	(1.090)	(1.157)	(1.149)	(1.164)	(1.038)
R&D investments	-0.634	-0.447	-0.450	-0.370	-0.175	-0.433	-0.844*	0.030
	(0.422)	(0.403)	(0.418)	(0.418)	(0.390)	(0.409)	(0.468)	(0.352)
Patents	0.033	0.052	0.042	0.070	0.001	0.056	-0.022	0.073
	(0.061)	(0.052)	(0.052)	(0.052)	(0.056)	(0.052)	(0.051)	(0.050)
UE with PhD	-0.593	-0.189	-0.122	-0.632	0.166	-0.223	0.197	0.886**
	(0.477)	(0.449)	(0.455)	(0.479)	(0.502)	(0.466)	(0.504)	(0.432)
UE with MBA	0.130	0.179	0.075	-0.390	0.335	0.096	-0.094	0.021
	(0.515)	(0.465)	(0.473)	(0.486)	(0.516)	(0.503)	(0.519)	(0.458)
UE international experience	0.728***	0.648***	0.693***	0.619***	0.668***	0.646***	0.492**	0.204
	(0.199)	(0.191)	(0.197)	(0.197)	(0.204)	(0.198)	(0.200)	(0.186)
UE industry experience	0.175	-0.361	-0.231	-0.287	-0.946	-0.404	-0.450	-0.739
	(0.901)	(0.805)	(0.809)	(0.805)	(0.857)	(0.798)	(0.802)	(0.787)
UE size	0.189	-0.055	-0.058	-0.104	-0.113	-0.101	-0.130	-0.285
	(0.219)	(0.184)	(0.184)	(0.186)	(0.203)	(0.187)	(0.188)	(0.178)
University-affiliated firms		0.491**	0.380*	0.134	0.152	0.328	0.474	0.116
		(0.221)	(0.226)	(0.378)	(0.767)	(0.314)	(0.323)	(0.299)
UNI_Prestige			5.776***	4.792***	8.199**	4.252**	4.815**	9.954*
			(2.200)	(1.852)	(3.815)	(1.878)	(2.076)	(5.994)
UNI_Internationalization				3.428**	4.866**	2.289***	2.271***	0.842
				(1.600)	(1.916)	(0.701)	(0.696)	(0.633)
US university	0.682*	0.209	0.070	0.360	0.372	0.494	0.410	0.023
	(0.389)	(0.405)	(0.423)	(0.440)	(0.413)	(0.433)	(0.449)	(0.416)
Biotechnology cluster	0.289	0.296	0.265	0.142	0.255	0.216	0.219	0.171
	(0.221)	(0.189)	(0.191)	(0.203)	(0.207)	(0.195)	(0.193)	(0.189)
Constant	-0.954	-0.627	-0.603	-1.074	-0.373	-0.546	0.046	0.840
	(1.299)	(1.073)	(1.091)	(1.067)	(1.136)	(1.093)	(1.083)	(0.991)
Observations	220	220	220	220	220	220	220	220
Pseudo R^2	0.181	0.188	0.198	0.243	0.364	0.227	0.187	0.160
Log-likelihood	-132.01	-130.96	-129.35	-122.62	-109.20	-124.64	-126.67	-145.05
$\chi 2$ test	57.79***	59.58***	68.80***	96.51***	74.50***	84.30***	60.41***	49.85**

Signals associated with the prestige and the internationalization can be jointly provided by the same academic institution influencing each other. The international outlook of universities can indeed contribute to the prestige of a university[1]. We address this potential endogeneity problem regressing the university prestige on the university internationalization, and using residuals from this regression as an instrumental variable in our analysis.

Table 7 reports the results. The coefficients of prestige and internationalization are all positive and strongly significant across the different specifications of internationalization (Models 1, 2 and 3). The two signals enhance the attractiveness for foreign acquirers even when we control for their dependence. This suggests that our second and third hypothesis apply also separately.

Table 7. Controlling the potential endogeneity problem between the university prestige and internationalization

Probit regressions on the probability of being the target in a cross-border M&A. UNI_Prestige is an instrumental variable identifying the residuals after being regressed on UNI_Internationalization. Country and year dummies are included in all models. Robust standard errors are in parentheses. Significance level of 1% (***), 5% (**), and 10% (*).

	(1)	(2)	(3)
	Teaching	Research	Third Mission
Firm size	0.030	0.053**	0.030
	(0.021)	(0.023)	(0.020)
Age	-0.056	-0.203	-0.096
	(0.183)	(0.193)	(0.180)
Growth rate	0.637***	0.486**	0.618***
	(0.208)	(0.210)	(0.216)
VC backed	0.337*	0.061	0.245
	(0.203)	(0.208)	(0.194)
Top-ranked underwriter	0.390**	0.145	0.325*
	(0.195)	(0.210)	(0.196)
Prone to IPO	-0.657	-1.677	-1.579
	(1.105)	(1.161)	(1.154)
R&D investments	-0.330	-0.178	-0.416
	(0.430)	(0.388)	(0.410)
Patents	0.067	0.000	0.054
	(0.053)	(0.056)	(0.052)
UE with PhD	-0.629	0.172	-0.212

[1] The ARWU ranking does not include any scores for university internationalization, while the THES ranking assigns a 5% weight to the percentage of full-time international professors and the percentage of full-time international students.

	(0.488)	(0.505)	(0.471)
UE with MBA	-0.546	0.321	0.088
	(0.503)	(0.524)	(0.518)
UE international experience	0.670***	0.694***	0.689***
	(0.201)	(0.208)	(0.201)
UE industry experience	-0.072	-0.911	-0.319
	(0.805)	(0.858)	(0.804)
UE size	-0.083	-0.110	-0.101
	(0.190)	(0.204)	(0.188)
University-affiliated firms	0.094	0.085	0.329
	(0.381)	(0.782)	(0.321)
UNI_Prestige	4.548**	7.930**	4.202**
	(1.822)	(3.735)	(1.873)
UNI_Internationalization	4.168***	5.702***	2.457***
	(1.606)	(1.945)	(0.709)
US university	0.344	0.346	0.474
	(0.441)	(0.433)	(0.437)
Biotechnology cluster	0.173	0.278	0.260
	(0.209)	(0.209)	(0.198)
Constant	-1.000	-0.304	-0.440
	(1.072)	(1.137)	(1.091)
Observations	220	220	220
Pseudo R^2	0.243	0.364	0.227
Log-likelihood	-122.62	-109.20	-124.64
$\chi 2$ test	96.51***	74.50***	84.30***

4.1 Robustness checks

In this section, we report the results of additional analyses performed to check the robustness of our results, including different measures for the probability of cross-border M&As, university affiliation and university prestige. First, we modify the time horizon for considering the cross-border M&A deals after the IPO, limiting our investigation to cross-border M&A deals occurred within 3 years after the IPO (Table 8, Model 1). Second, we apply an alternative definition of university affiliation by defining firms as university-affiliated only if a university holds a stake in the equity at the IPO (Table 8, Model 2). Third, a different international ranking is included to measure the prestige of a university, the Times Higher Education Supplement (Table 8, Model 3). Our results are confirmed.

Furthermore, we test the robustness of the results considering two different econometric models, with different dependent variables. We employ a tobit regression model on the relative number of cross-border M&A deals as a target (Table 8, Model 4), and a negative binomial regression model on the number of cross-border M&As within 5 years after the IPO (Table 8, Model 5). In both cases, controlling for the prestige and the

internationalization of universities, the affiliation itself is not statistically significant, while the prestige and the internationalization of a university remain strongly significant. Thus, these alternative models confirm our findings.

Table 8. Robustness checks

Models (1), (2), and (3) are probit regressions on the probability of being the target in a cross-border M&A. Model (1) considers as dependent variable the probability of being targeted in at least one cross-border M&A deal within three years, rather than five years as in all other models. Model (2) includes an alternative definition of university affiliation (i.e. when a university holds a stake in the equity of the firm at the IPO). Model (3) considers the THES (Times Higher Education Supplement) ranking as an alternative measure for the university prestige. Model (4) is a tobit regression where the dependent variable is the ratio of cross-border M&As as target within five years. Model (5) is a negative binomial regression where the dependent variable is the number of cross-border M&As as target within five years. All models consider the Third Mission activity as a proxy for university internationalization. Country and year dummies are included in all models. Robust standard errors are in parentheses. Significance level of 1% (***), 5% (**), and 10% (*).

	Probit			Tobit model	Negative Binomial model
	(1)	(2)	(3)	(4)	(5)
Firm size	0.013	0.033	0.030	0.026	0.044*
	(0.020)	(0.020)	(0.021)	(0.034)	(0.023)
Age	-0.186	-0.084	-0.036	0.137	-0.154
	(0.185)	(0.181)	(0.182)	(0.293)	(0.203)
Growth rate	0.355*	0.518**	0.566**	1.015**	0.408**
	(0.196)	(0.209)	(0.230)	(0.417)	(0.161)
VC backed	0.215	0.248	0.177	0.434	0.312
	(0.200)	(0.189)	(0.196)	(0.335)	(0.192)
Top-ranked underwriter	0.373*	0.336*	0.348*	0.552*	0.336*
	(0.197)	(0.193)	(0.194)	(0.326)	(0.188)
R&D investments	-0.297	-0.422	-0.440	-0.590	-0.204
	(0.432)	(0.419)	(0.415)	(0.695)	(0.552)
Patents	0.044	0.052	0.042	0.119	0.031
	(0.053)	(0.052)	(0.054)	(0.093)	(0.053)
Prone to IPO	-1.883*	-1.593	-1.299	-1.572	-1.699
	(1.128)	(1.159)	(1.135)	(1.763)	(1.290)
UE with PhD	-0.207	-0.252	0.000	-0.923	-0.126
	(0.501)	(0.470)	(0.478)	(0.797)	(0.479)
UE with MBA	-0.252	0.120	-0.061	-0.167	0.035
	(0.534)	(0.493)	(0.480)	(0.915)	(0.419)
UE international experience	0.473**	0.672***	0.625***	0.759**	0.664***
	(0.199)	(0.198)	(0.201)	(0.355)	(0.250)
UE industry experience	-0.390	-0.422	-0.373	-0.244	-1.234
	(0.824)	(0.794)	(0.809)	(1.348)	(0.858)
UE size	-0.124	-0.076	-0.084	-0.222	-0.057
	(0.190)	(0.188)	(0.190)	(0.309)	(0.193)
University-affiliated firms	0.075	0.180	0.424	0.484	0.376
	(0.310)	(0.302)	(0.325)	(0.554)	(0.316)
UNI_Prestige	4.916**	4.004**	74.208**	7.785**	2.851**
	(2.167)	(1.853)	(37.694)	(3.293)	(1.212)
UNI_Internationalization	1.976***	1.694***	1.899**	4.280***	2.007***
	(0.729)	(0.511)	(0.786)	(1.293)	(0.487)
US university	0.572	0.221	0.355	1.162	0.364

	(0.422)	(0.399)	(0.496)	(0.759)	(0.369)
Biotechnology cluster	-0.174	0.230	0.187	0.540	-0.106
	(0.209)	(0.195)	(0.201)	(0.336)	(0.202)
Constant	0.276	-0.616	-0.723	-1.697	-0.782
	(1.084)	(1.103)	(1.097)	(1.768)	(1.264)
Observations	220	220	220	220	220
Pseudo R^2	0.225	0.221	0.256	0.184	0.140
Log-likelihood	-115.19	-125.57	-119.54	-168.55	-170.05
$\chi 2$ test	77.50***	81.63***	69.02***	75.55***	111.33***

5. Conclusions

In this work, we investigate the role of the affiliation with a university in the cross-border M&A activity of a sample of 220 biotech firms that went public in Europe over the period 1995-2006. Even controlling for the quality of a firm at the time of the IPO and the international experience of its upper echelons, we find that the affiliation with a university positively influences the attractiveness of firms in the eyes of foreign acquirers. The more prestigious and internationalized is the university, the more is the interest from international partners. The role of university prestige is relevant for both domestic and cross-border M&As, while the internationalization of a university plays a determinant role in attracting international acquirers since it contributes to mitigate the problems associated to the liability of foreignness.

As far as new research trajectories are needed in the academic entrepreneurship literature to tease out the role of universities in the current society (Wright 2014), we shed light on the role played by internationalized universities in fostering the internationalization process of affiliated firms. Although policy makers and university managers have devoted primary attention to the ongoing phenomenon of university internationalization, the implications and, in particular, the positive externalities of the process are far from being investigated. In addition to their primary scope of competing in the international context for students, faculty and research funds, our results show how the international characterization of university plays a significant role in certifying the entrepreneurial activity of affiliated firms. Indeed, among the biotech firms that went public in Europe in the period 1990-2006, 72% of those affiliated with a highly internationalized university were targeted in cross-border M&As. International investors

clearly appreciate the potential of such affiliated firms, preferring them in cross-border M&A activity.

Internationalized universities may create symbiotic relationships with firms, and, similarly to what multinational enterprises do, act as intermediaries of internationalization (Acs and Terjesen 2013). They enable the international expansion of affiliated firms thanks to knowledge spillovers or because of the availability of geographically bounded resources. The significant role of academic entrepreneurship in generating and sustaining the regional economic growth and competitiveness is thus amplified when they provide regions the benefits of a greater international academic entrepreneurial activity. Regions may consequently exploit internationally involved firms to foster their economic and social growth in a global context.

This paper offers managerial insights for current science-based entrepreneurs, who plan to enter the "market for assets". Their firms could be preferred targets in international acquisitions when affiliated with eminent and internationalized universities. From the perspective of international acquirers, we highlight that the sheer fact that a foreign firm acquires a local partner might be not sufficient to meet the requirement of legitimacy in the host country. The acquisition of a university-affiliated firm may help to certificate the acquirer in the local environment because of the university local embeddedness. To this extent, the role of prestigious, international universities is particularly effective.

This study suggests promising avenues for further research. Prior international experiences of upper echelons are found to be important drivers of the appeal of entrepreneurial firms as targets in M&A deals. This could be a signal of the prior interest of the firm to be involved in an international acquisition. The involvement in such operations depends indeed not only on the interest of the acquirer but also on the valorization strategy of the target. The impact of international experience of upper echelons on the proactiveness in the international M&A markets is worth further research. The present paper provides evidence on the impact of internationalized universities in increasing the attractiveness of IPO firms to foreign investors. This is only one of the possible universities' positive externalities. Therefore, further research could focus on a broader definition of knowledge spillovers arising from internationalized universities on the local entrepreneurial environment, both in terms of research output and human capital

outflow. As the new role of universities in the entrepreneurial society is evolves in creating valuable "entrepreneurial capital", in the form of leadership for creating entrepreneurial thinking, actions and institutions (Audretsch 2014), internationalized universities may generate more benefits for regions' development and competitiveness, well beyond the development of technology transfer, as patents and university spinoffs.

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CHAPTER 3: The dynamic of university spatial competition for students: The Italian case

Revised and Resubmitted to *Regional Studies*

Abstract

The ability to attract students has progressively become a crucial factor for the survival of universities in Southern European countries, due to decreasing governmental funding. Using a competing destinations model for the population of 75 Italian universities in the period 2002-2012, this paper investigates whether they compete for students and how this rivalry has evolved in response to changing enrolment demand. First, we find that there is competition for students among Italian universities. Second, we document that the characteristics of the competition forces changed after the recent financial crisis, with universities located in close proximity to others (i.e., belonging to agglomerated "clusters") becoming more attractive to students.

Keywords: University competition; student attractiveness; higher education market; Italy

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1. Introduction

In the wake of cuts to government funding for higher education systems in Southern European countries (EUA 2013; 2014), collecting financial resources has become a priority when the universities set strategies to ensure the pursuit of their daily core activities and long-term survivability (Wangenge-Ouma and Langa 2010; Christopherson, Gertler, and Gray 2014). Thus, in addition to attracting more financial resources by intensifying their interactions with industry (Muscio, Quaglione, and Vallanti 2013), increasing their attractiveness to students has become a crucial activity for universities (Wilkins, Shams, and Huisman 2013; Donina, Meoli, and Paleari 2014; Teixeira et al. 2014), especially for institutions relying on tuition fees for a significant portion of their budgets (e.g., Maltz, Murphy, and Hand 2007). Furthermore, university competition for students has been significantly exacerbated by the overall decrease of student populations which may result from both demographic issues and economic difficulties (EUA 2013).

The fiercely competitive environment that has consequently emerged among universities has led them to increase their focus on the determinants of their attractiveness to students. It is acknowledged that university characteristics, such as the quality (Long 2004; Ciriaci 2013), the average tuition fee (Allen and Shen 1999; Mitze, Burgard, and Alecke 2014), and their image at a national and international level (Marginson 2006), drive students' decisions. However, the context where universities operate inevitably shapes the extent to which such characteristics provide universities with a competitive advantage. While university competition takes primarily place at a local level, whereby universities attempt to attract additional students in competition with nearby competitors, it also extends to more distant universities due to the increased mobility of students in recent decades (Hoxby 1997; 1998). The spatial dimension is therefore crucial to an in-depth investigation of universities' attractiveness to students in the light of the competitive environment in which they operate (Sà, Florax, and Rietveld 2004).

Nevertheless, competition among actors is a dynamic issue, and its temporal aspect cannot be neglected, as the interactions among competitors evolve over time depending on environmental variations (Chesson 2000). Consistent with the resource-advantage theory (Hunt and Morgan 1996), university competition is an ongoing process

that consists in a continuous struggle among institutions to achieve a comparative advantage in a dynamically changing environment. Notwithstanding that universities' actions are affected by societal and economic changes (Long 2013), which inevitably influence the behaviour of both the consumers (students) and providers (universities) in the higher education market, this paper is the first attempt to fully explore the evolution of the competition among universities over time.

This paper analyses the presence of university competition for (first-year, first-time) students using the population of 75 universities in Italy over the period 2002-2012. As an example of a Southern European country, Italy represents an interesting setting to investigate the dynamics of university competition. The Italian higher education market has evolved over the last decade due to the increasing rivalry aroused among universities to attract more students and mitigate reduced government funding (CNVSU 2011). Students have been regarded as primary resources who directly pay tuition fees and indirectly attract government transfers, which have been increasingly made proportional to the universities' actual expenditures per student enrolled (Agasisti 2009; Rossi 2010). The competition for additional students has consequently become a crucial activity for the sustainability of the entire Italian university system. Thus, the novelty of our research is twofold: to the best of our knowledge, this is the first paper aimed to study the evolution of university competition over time, and it is the first study that fully investigates the effect of such competition on university attractiveness to students in the Italian higher education market.

We investigate whether universities' ability to attract students is characterised by competition forces by using a competing destinations model, namely a spatial-interaction model accounting for the alternative choices students may employ for spatial decision-making (Fotheringham et al. 2001). For each university, we compute a *competitors' proximity index,* i.e. the distance-weighted characteristics of attractiveness of all university competitors, to evaluate the competition forces each university is subjected to from all other university destinations (e.g., Sà, Florax, and Rietveld 2004). Relying on the population of Italian universities, we examine the impact of competition forces on the student attraction to Italian universities and the evolution of competition dynamics during the period 2002-2012, with a focus on the effects of the financial crisis.

Controlling for the characteristics of university attractiveness (its image at a local and national level, average fees per student, and amount of teaching resources) and the socio-economic features of both the province (NUTS – 3 region) where each university is located and the student's province of origin (value added per capita, and quality of life), we provide evidence that Italian universities have been subject to enrolment competition over the last decade, thereby influencing their attractiveness to students. Second, by evaluating such competition over time, we document that the recent financial crisis led students and families to be more selective when choosing a university. By isolating the effects of competition forces during the period 2009-2012, we find that universities in close proximity to others, and therefore those more likely to have faced a higher level of competition, have become more attractive.

This paper is organised as follows. Section 2 presents the literature review and develops the testable hypotheses. Section 3 describes the Italian higher education market. Section 4 presents the research design. Section 5 reports the results, and Section 6 concludes the paper.

2. Theoretical background and testable hypotheses

Former literature on university competition defines that there are two types of competition for students among universities, for the *best* and the *most* students (Marginson 2006). The former form of competition serves to increase universities' value on the higher education market based on the ability of their students, who are screened using restrictive admission standards (Epple, Romano, and Sieg 2003; Gu 2012). From a hierarchical perspective, top-tier universities (research institutions) ensure their research capacity over time by relying on the most talented students (Marginson 2006; Horta 2009). In contrast, competition on quantity (number of students) is primarily intended to attract additional funds and ensure the survival of the institution over time. In this case, admission standards are quite similar across different institutions within a system (De Fraja and Iossa 2002) and are not generally restrictive (as in the case of Italy, Rossi 2009). Relying on the competition to attract additional students, we develop the following two hypotheses.

Drawing on a customer-input technology perspective (Rothschild and White 1995), the reason why universities compete to attract students is twofold. Students are both inputs of educational services and consumers. They provide funds to the universities by directly paying tuition fees and indirectly by leading to the transfer of proportional financial resources from the government. As the primary institutions providing tertiary education and given the need to be financially sustainable, universities consider their attractiveness to students to be a priority in their agenda (Gu, 2012).

To increase their attractiveness, universities must address the several determinants that characterise students' decision-making process (for a review, see Sà, Florax, and Rietveld 2004; 2006). This strand of the literature highlights that at an *individual* level, parents' education, income and jobs, the student's age and the type of secondary school attended are among the most important individual factors influencing the selection of a specific university. While, at the *university* level, its quality, reputation, and average tuition fee are considered to play a fundamental role when students select their best alternative for post-secondary education. Further, the socio-economic characteristics of the areas in which universities are located crucially contribute to determine the students' decision-making, primarily because of the various employment opportunities and lifestyles that regions might offer (Ciriaci 2013).

Notwithstanding all of these factors, the attractiveness of universities cannot be assessed in isolation from the local environment where they operate (Hoxby 1998). Universities might be located in markets with a high level of competitive pressure due to the proximity of their competitors. Their capacity to attract students is strongly influenced by the presence and the activities of neighboring universities (Gu 2012). According to the theory of competitive systems (Chesson 2000), which predicts that the frequency and intensity of competitive interactions among universities are primarily associated with their local spatial interactions, the higher the number of universities in close proximity, the more intense the competition universities are subjected to.

Moreover, the increased geographical integration that has characterised the higher education system over the last two decades progressively led universities to compete for a new pool of geographically dispersed students (McMillen, Singell, and Waddell 2007; Ghosh 2010). Students are currently sorted more thoroughly among different universities based on their specific demands for education. Thus, in addition to their known local

competitors, universities might face new potential competitors at the national level, losing their local power (Hoxby 1998). In other words, competition among universities also exists among institutions that are not in close proximity. In this work, we hypothesise that, *ceteris paribus*, the presence of competition decreases the number of students that each university might attract.

Hypothesis 1*: The higher the level of competition a university is subjected to, the lower the number of students that a university will enrol.*

The recent financial crisis influenced both the activity of universities and students' propensity to enrol. On the supply side, universities have been increasingly financially constrained and forced to find new sources of external funding to pursue their daily activities. Consequently, in addition to the intensification of their interactions with the business sector, the scarcity of resources makes increasing student enrolment a priority for academic institutions (Rossi 2010; Gu 2012; Donina, Meoli, and Paleari 2014; Teixeira et al. 2014). On the demand side, families have experienced significant financial difficulties that inevitably impacted their ability to afford and willingness to pay for students' post-secondary education (Long 2013). Reduced income has gradually decreased households' ability to provide youths with a higher level of education, primarily because of the impossibility to support the costs of education or the expectation of future unemployment (e.g., Riphahn 2002).

In periods of economic difficulty, the fact that higher education serves as a positional good (Hirsch 1976), meaning that certain places offer better social status and livelihoods than others, is even more heightened. Specifically, the choice of a university is driven not only by a human capital dimension, where the value of graduating is a function of the intrinsic quality of students, teachers and the services provided by the university, but also by a relative dimension, which implies that students' choice highly depends on the recognition of a university throughout the entire system (Marginson 2006). Students therefore become more selective in choosing post-secondary education to increase the expectation of better opportunities in the labour market and potential to increase their social status in the future. Once families decide to provide post-secondary education to their children, the choice of a university is more selective due to the greater

financial constraints they face, with the primary aim of increasing the relative advantage their children will enjoy in the future. Todays, families have more concrete tools to operate more selective choices due to a faster and greater access to information (e.g., internet) facilitating information searching and decision making.

Consequently, during periods of higher uncertainty, the choice of a post-secondary education may be affected by the fact that certain universities have operated in more competitive environments. To remain competitive, the racing behaviour of competing universities leads them to develop and increase valuable services and facilities for their "stakeholders" (Porter and Kramer 2002). The competitors continuously present a moving target for the other universities belonging to the same competitive environment, promoting a "*Red Queen effect*"- i.e., a university must run simply to maintain its position (e.g., Barnett 1997). Universities that are subject to higher levels of competition become more attractive during periods of economic/financial crisis, as students consider them to be more valuable and less risky options in the long run. Thus, while competition might decrease the number of students that rival universities can enrol in a first stage, it contributes to create a more competitive framework wherein rival universities become more attractive for students afterwards.

Hypothesis 2*: Since the financial crisis, the negative effect of university competition on attractiveness to students is expected to decrease.*

3. The evolution of the Italian higher education market for students

In Italy, the implementation of the two-level qualification system (bachelor's and master's degrees) occurred at the beginning of the twenty-first century, with Law no. 30, February 10, 2000 ("*Legge Quadro in materia di Riordino dei Cicli dell'Istruzione"*). This reform represented an important change in the management of universities' strategic activities, thereby affecting how universities compete for students. Indeed, at the bachelor's degree level, competition primarily arises among universities to attract additional students, while at the master's degree level, academic institutions are more focused on pursuing a higher level of quality and consequently set admissions standards to master's students.

Following this reform, the Italian framework underwent further important transformations affecting both the market structure of the university system and the demand for post-secondary education, which makes of Italy an interesting setting to empirically test our predictions. First, the system experienced declining enrolment, which required universities to formulate new strategies to foster their attractiveness to students. The total number of enrolled students in 2012 was 13% lower than that in 2002, while the higher education system evolved with the creation of 3 new traditional universities and 11 distance-learning institutions. As a direct consequence, the number of students that universities could attract decreased over the last decade. The universities' need to attract students was further exacerbated by repeated reductions in the percentage of state-allocated funds – *Fondo di Finanziamento Ordinario* (FFO) – in the universities' total income (CNVSU 2011). Moreover, the *Ministry of University and Research* (MIUR) has increasingly made the allocation of governmental funds (FFO) proportional to the universities' actual expenditures per student enrolled (Rossi 2010).[1] The importance of students as crucial factors determining universities' total incomes is also related to the fact that in the period 2001-2009,[2] the weight of tuition fees in the universities' total budgets increased by 20% (CNVSU 2011).

Second, the higher education market has changed; the rivalry among local universities is now supplemented by competition from numerous academic institutions at the national level. Universities have faced a new pool of potential students that has become increasingly geographically dispersed. Further, the shares of students enrolled originating from different provinces has constantly increased over time. Specifically, the concentration of student's provinces of residence decreased by nearly 10% at the national level during the period 2002-2012.

Lastly, it is noteworthy to highlight that in Italy the attractiveness to students is characterized by a peculiarity of the higher education system, that of the *legal value of a degree*. While the government developed incentives to increase the average quality of the system, the legal value of a degree limited students in selecting the highest quality

[1] In 2013, 13.5% (K€ 819,000) of total state funding was competitively allocated, of which 66% relates to the education process.

[2] We rely on the most recent data provided by the Comitato nazionale per la valutazione del sistema universitario (CNVSU).

universities (Donina, Meoli, and Paleari 2014). The degrees delivered by academic institutions are considered equivalent by the law, no matter if the different institutions have different reputation. Hence, these patterns could be responsible of a distortion in the students' decision making process, where the quality of a university does not represent a main determinant in the choice.

4. Research design

4.1. The competing destinations model

To analyse the effects of university competition on universities' attractiveness to students and its evolution over time, we estimate a spatial-interaction model in the form of a gravity equation of student flows. In other words, we model the universities' attractiveness to inter-provincial students as the forces of attraction/repulsion that arise in the trade between a pair of countries or regions (e.g., Etzo 2011). To address student origin, we rely on the province as the most detailed level of analysis. Equation (1) models student flows as a positive function of the attractive mass of the province of origin and the university of destination and a negative function of the distance between them. Specifically:

(1) $$F_{i,j,t} = O_{(\mathrm{Prov}_{i,t})}\, D_{(Univ_{j,t};\mathrm{Prov}_{j,t})} f(d_{i,j})$$

where $F_{i,j,t}$ is the flow of students from province i to university j in year t; $O_{(\mathrm{Prov_{i,t}})}$ represents the socio-economic characteristics (the mass) of province i that influence students' departure from it (the population of university students, value added per capita, average quality of life of persons living there in year t); $D_{j,t}$ represents the mass of university j, depending on both the province of destination features ($Prov_{J,t}$) and the university's attractiveness to students ($Univ_{j,t}$) in year t; the latter is a multifactorial phenomenon, measured here as the number of registered students, the number of teaching resources in classes, the image of the university at a local and national level, and the average tuition fee students must pay for post-secondary education at each university in year t. As in the case of the province of origin, we control for the value added per capita

and the quality of life for the province of destination. Finally, $f(d_{i,j})$ is a decay function of the Euclidean distance between province *i* and university *j* for each flow of students. All variables are defined in detail in sub-section 4.4.

The model described in equation (1) assumes that individuals have a flat information processing strategy, namely they are unable to make decisions from restricted choice sets rather than the complete set. However, we acknowledge that a hierarchical information processing system is in place during the students' decision-making process (Moogan, Baron, and Harris 1999; Dawes and Brown 2005). Students are acknowledged to ex-ante select spatial clusters of universities and gradually limit their choice to a specific set of destinations (e.g., Sà, Florax, and Rietveld 2004). To consider how students process spatial information, we employ a competing destinations model (e.g., Fotheringham 1983; 1985; 2001) which allows to identify the presence of competition or agglomeration forces among universities. Following Sà, Florax, and Rietveld (2004), equation (1) is therefore calibrated with the inclusion of a *Competitors' proximity index* ($CPI_{j,t}$) that accounts for the extent to which a university is distant, both in physical (km) and operative terms, from its competitors:

(2) $$F_{i,j,t} = O_{(\mathrm{Prov}_{i,t})}\, D_{(Univ_{j,t};CPI_{j,t};\mathrm{Prov}_{j,t})} f(d_{i,j})$$

where:

(3) $$CPI_{j,t} = \sum_{\substack{m=1 \\ m \neq j}}^{N} (Univ_{m,t}) f(d_{j,m})$$

$CPI_{j,t}$ is the *Competitor's proximity index* for university *j* in year *t*; N stands for all other universities *m* in the higher education system except for university *j*; ($Univ_{m,t}$) reflects the characteristics of students' attraction to the university destination *m*; $f(d_{j,m})$ is a decay function of the Euclidean distance between university *j* and university *m*. As highlighted by Fotheringham et al. (2001), the sign of the estimated *Competitors' proximity parameter* provides important information on the destinations' interactions. In case that the estimated coefficient is negative, competition forces among universities exist, while agglomeration effects are present when it is positive.

As educational programmes change from university to university influencing, *ceteris paribus*, the distribution of students among various universities (Seeber et al. 2012), we employ a more detailed *Competitor's proximity index* to corroborate the estimations. Based on the assumption that the more specialised the disciplines of institutions are (niche-seeking strategy), the lower the level of competition to which they are subjected (Rossi 2009; 2010), we weight the *Competitors' proximity index* with respect to the department[3] overlap that exists between different universities. We consider the department as the level of analysis to make the investigation clearer and objective due to the presence of a large variety of degree programmes in Italy, each of which is characterised by its own peculiarities[4]. Our rationale is that two or more universities can be geographically proximate but may not compete against one another because they have different departments. The *Competitors' proximity index* is corrected for the set of feasible choices students face given the universities' department types. For each pair of universities, we first identify the departments in common as in equation (4). Specifically, $DEP_{OV_{i-j}}$ is the department overlap between university *i* and university *j*, where DEP_i stand for the departments of university *i* and DEP_j those in place at university *j*:

$$DEP_{OV_{i-j}} = \left(DEP_i \cap DEP_j\right) \tag{4}$$

Second, we compute the overlapping index between universities *i* and *j* by multiplying the relative shares of students enrolled in the departments of university *i* that also exist at university *j*:

$$IDEP_{OV_{i-j}} = \left(\frac{\sum StudUniv_i \in DEP_{OV_{i-j}}}{\sum StudUniv_i}\right) X \left(\frac{\sum StudUniv_j \in DEP_{OV_{i-j}}}{\sum StudUniv_j}\right) \tag{5}$$

[3] Law 240/2010 profoundly affected the structure of Italian universities. A structure composed by two internal organizational units, namely the faculties and the departments, were replaced by a single internal scientific structure with new roles: the departments (Donina, Meoli, and Paleari 2014).

[4] Italian universities' freedom to establish courses of study increased after 1993, while highly restrictive quality standards for the creation of new programmes were implemented in 2007 (Ministerial Decree 554/2007).

As an example, we consider two universities in the North of Italy, the University of Bergamo and the Polytechnic University of Milan; they both offer Engineering. However, Law, Foreign Languages, Literature and Communication Studies, Human and Social Sciences, and Letters and Philosophy are only offered at Bergamo, while the Polytechnic University of Milan offers Architecture and Design. The first ratio is equal to 0.14, as the number of students that Bergamo enrols in Engineering (which is also offered by Milan) (344) over the total number of student flows (2,449). Similarly, the second ratio is equal to 0.67 after excluding the students belonging to the departments of Architecture and Design (4,415) in Milan. The product of these two ratios ($DEP_{OV_{m-j,t}}$) is used to weight the *Competitors' proximity index* as follows:

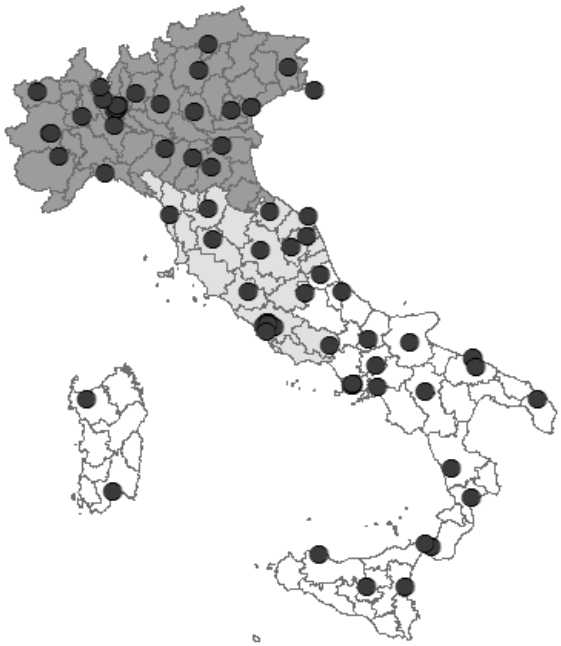
$$CPI_{j,t} = \sum_{\substack{m=1 \\ m \neq j}}^{N} (Univ_{m,t} DEP_{OV_{m-j,t}}) f(d_{j,m}) \quad (6)$$

We investigate university competition considering the population of Italian universities during the period 2002-2012[5]. After excluding 11 long-distance-learning institutions, 6 doctoral universities (e.g., IMT Institute for Advanced Studies Lucca, Sant'Anna School of Advanced Studies) and 3 universities for foreigners (University of Foreigners of Perugia, of Reggio Calabria, and of Siena), as these institutions fill specific niches in the higher education market[6], our hypotheses are tested considering 75 universities. Figure 1 depicts the geographical distributions of universities in 2012 using the coordinates of the university's legal place of residence[7]. As far as Italy is acknowledged to be characterised by an important social-economic divide we rely on the ISTAT (*The Italian National Institute of Statistics)* classification of macro-areas (North, Centre and South of Italy) to highlight the regions where universities are located. 30 universities are established in the North (darker grey areas), 19 in the Centre (light grey areas), and there are 26 academic institutions in the South, including the Islands (white areas).

[5] Three universities were established during the period of investigation: *Kore - University of Enna* (2004); *Bra - University of Gastronomic Sciences* (2004); *European University of Rome* (2005).
[6] The *Rome – Link Campus University* is also excluded because it was accredited as a university in the second half of 2011 (decree no. 374 of September 21, 2011).
[7] In Italy, the average distance among the campuses of a given university is less than 6 km.

Figure 1. Geographical distribution of Italian universities

Macro-areas are identified by different colours. Northern provinces are in darker grey; central provinces are in light grey; and southern provinces are reported in white. Circles represent the geographical distribution of the 75 universities at the national level.



Data on Italian universities are gathered from the online database made available by the MIUR. It provides specific data for each university over time: students, professors, technical staff and courses. At the province level, we collect data using the statistics provided by ISTAT and the main Italian financial newspaper, *Il Sole 24 Ore.*

4.2. Variables description

This section presents the variables employed in the empirical analysis. We first list the dependent and independent variables of our model and the distance-decay parameter. Second, the measures impacting student mobility are described for the province of origin, the university and the province of destination.

Flows of students: As a *dependent variable,* we consider the flows of first-year enrolled students for the bachelor's and 5-year degree ("*Ciclo Unico*") level from all Italian provinces to each university. International students are excluded from our analysis, as our

aim is to assess the spatial dimension of university competition with respect to national resources.

Competitors' proximity index: The parameter (*independent variable*) included in equation (3) for the universities' attractiveness to students ($\boldsymbol{Univ_{m,t}}$) relies on the size of each university, measured as the total number of registered students (bachelor's and master's) (Sà, Florax, and Rietveld 2004). This measure represents a catchall variable for all the types of services (Harman 2000), greater diversity in faculties (Bonaccorsi, Daraio, and Simar 2006), networks and national and international visibility (Lepori et al. 2013) that larger universities are supposed to offer their students. Large universities are also more equipped to attract EU-funding projects (Geuna 1998), which contributes to improving their reputation in the eyes of potential students and external stakeholders.

Distance between the province of origin and the university of destination: The distance represents a physical barrier to student mobility with respect to new university destinations. Here, the distance-decay parameter is measured by considering the legal residence of the university (destination) and the capital of each province (origin) for the percentage of population of students living in the capital city. In contrast, for the share of the student population living in intrazonal areas, we calculate the university-province distance by relying on the formula used by Rietveld and Bruinsma (1998)[8], where provinces are assumed to be circular and all areas homogeneously intensively used. As no reliable data on travel time can be obtained for different modes of transportation (e.g., bicycles, buses, cars, etc.) and due to the high correlation between travel time and road distance (Rietveld et al. 1999), we refer to road distances. The functional form considered is an inverse of the distance $d_{i,j}$.[9] The same decay function is considered when computing the distance among universities in equation (6).

4.2.1. The characteristics of the university of destination

University size: As in any typical gravity model, we capture the effects of destination size, measured by the total number of registered students in each university.

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[8] $d_{intra-regional} = \frac{(\pi-1)}{\pi}\left(\sqrt{\frac{s_p}{\pi}}\right)$

Where s_p = area of province p, measured in square metres.

[9] The results are consistent when we consider a negative exponential distance decay function.

University teaching resources: Students consider the overall quality of a university in their decision-making process, primarily with respect to the resources available for teaching (Drewes and Michael 2006). We control for university teaching resources using the faculty-student ratio, measured as the number of professors per student. This indicator represents a good proxy for teaching resources in general (e.g., Huang 2012) and captures the opportunities for student learning in classes. An increase in the ratio indicates an increase in university inputs, in the quality of the academic programme and, more generally, of institutions, which is one of the determinants of the students' university decisions (Tavares and Cardoso 2013).

University's average tuition fee: The demand for higher education varies with the costs of schooling (e.g., Hübner 2012; Wilkins, Shams, and Huisman 2013). We consider the average tuition fee that students must pay to attend courses at a specific university. To account for the large differences across Italian provinces, primarily between those located in the South and in the North, we use the ratio of the total contribution of bachelor's & baster's students to the total number of students attending university *i*, scaled by the value added per capita of the student's province of origin.[10]

University legitimacy: The students' selection of a university might refer to the evaluation of the image of a university at the national level, as the legitimacy of its actions– i.e., that they are appropriate and acceptable to society (Suchman 1995). Institutions are known to develop multiple interorganisational relationships to increase their legitimacy (see Barringer and Harrison 2000), which, in the higher education context, could enhance the value of an academic degree in the job market. Employability is one of the primary reasons to attend higher education. We measure the legitimacy of a university by relying on its public endorsement in articles in national, regional and local newspapers (Desai 2008). The number of articles pertaining to each university for each year is collected using the Factiva news media database[11].

[10] GDP per capita is collected at the regional level in the period 2002-2012 using Eurostat data.
[11] See Cattaneo, Meoli, and Signori (2014)) for a description of the data collection procedure.

4.2.2. The characteristics of the province of origin and the province of destination

Size of the province of origin: The size of the origin is included as one of the two attractive masses in the gravity model. It represents the population of university students located in the province of origin (*Student population*). In particular, we consider the total number of first-year, first-time-enrolled students from each province of origin.

Value added per capita: The value added per capita of both the province of origin and the destination province are included to capture the effects of economic disparities between areas (e.g., Glaeser 2008).[12] The effects of different economic conditions, such as wage levels and the employment rate, influence the mobility of students to and from a specific area. ISTAT provides data on the per capita value added for each province until 2008 (*Sistema di Indicatori Territoriali*). We use Eurostat regional data to estimate the remaining values and complete our panel dataset.

Quality of life: As students' decision to move may be driven not only by economic reasons but also by consumer amenities such as theatres, museums and higher levels of tolerance (Florida 2002), we consider the annual position of each province in the quality of life ranking produced by the Italian financial newspaper *Il Sole 24 Ore* as in Ciriaci (2013). Both the province of origin and that of destination have been scored as (*Quality of life ranking*)$^{-1}$.We expect that the higher the quality of life in the province of destination, the greater the attractiveness of a university located in that province. Conversely, when the province of origin is characterised by a high level of quality, this is, all other things being equal, reduces the propensity of student to migrate to attend university in another province.

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[12] Despite the creation of three new provinces (Fermo, Monza-Brianza, Barletta-Andria-Trani) in 2004, which became active in 2009, data on their value added per capita are aggregated at the level of the former provinces (http://dati.italiaitalie.it/i-dati/per-territorio.aspx). In particular, the data on the province of Ascoli-Piceno include those of the new province of Fermo, the data on the province of Milan include those of Monza-Brianza and, similarly, the province of Bari aggregates the data of Barletta-Andria-Trani. As the student flows data provided by the Ministry of University and Research are disaggregated among these new provinces beginning in the 2004-2005 academic year, we re-distributed the value added per capita between the new and original; provinces according to their level of population (Geo Demo Istat). This is intended to increase the accuracy of our analysis.

In the Appendix, we report the correlation matrix for all variables.

4.3. Descriptive statistics

Table 1 reports the descriptive statistics at the university level in the period 2002-2012, disaggregating the data by macro-regions due to the regional economic divide that has thus far characterised Italy: the North, the Centre and the South (including Islands).

Table 1. Descriptive statistics by Italian macro-region

Geographic areas and university characteristics		*2002*	*2012*	*Δ% (2002-20012)*
North				
Flows of first-year, first-time enrolled students	Tot.	116,716	107,800	-7.64%
No. of students (BA & Masters)	Tot.	691,749	690,519	-0.18%
No. of professors	Tot.	23,350	23,131	-0.94%
University's average tuition fee	Avg.	1,085.43	1,624.86	49.70%
University legitimacy	Avg.	214.93	703.93	227.52%
Competitors' proximity index	Avg.	21,955.35	21,606.36	-1.59%
Obs.		29	30	
Centre				
Flows of first-year, first-time enrolled students	Tot.	74,673	61,268	-17.95%
No. of students (BA & Masters)	Tot.	456,103	424,484	-6.93%
No. of professors	Tot.	13,698	14,836	8.31%
University's average tuition fee	Avg.	750.93	1,063.28	41.60%
University legitimacy	Avg.	116.55	494.68	324.44%
Competitors' proximity index	Avg.	24,823.08	23,694.53	-4.55%
Obs.		18	19	
South				
Flows of first-year, first-time enrolled students	Tot.	106,356	83,479	-21.51%
No. of students (BA & Masters)	Tot.	633,801	609,522	-3.83%
No. of professors	Tot.	17,430	16,618	-4.66%
University's average tuition fee	Avg.	433.12	670.99	54.92%
University legitimacy	Avg.	60.09	258.92	330.89%
Competitors' proximity index	Avg.	38,028.78	34,181.25	-10.12%
Obs.		25	26	

An overall decrease in the university student flows was observed in each macro-region over the last decade. Southern academic institutions suffered to a greater extent (-22% South vs. -18% in the Centre and -8% in the North), as students have higher expectations of obtaining better job opportunities and expect a lower likelihood of being unemployed after graduation in the Northern regions (Bacci et al. 2008; Ciriaci 2013). The scenario is somewhat different when considering the total number of students registered in the system. Universities located in the central regions were affected by a larger loss of students (-7%) than that observed in the South (-4%). Nevertheless, Northern universities did not experience a loss of students because of the more pronounced interregional migration of students towards Northern regions (Ciriaci 2013). The total number of professors grew by 8% in the Centre, with a consequent increase in the teaching resources available to students attending classes there. In contrast, Southern universities reported a loss of teaching staff (-5%), while a small decrease occurred in the North (-1%). On average, the cost to attend post-secondary education increased throughout the Italian peninsula by nearly 50% in each macro-area. Students seeking to attend a university in the North were required to spend one thousand euros more than those in the South in 2012, despite the smaller difference that characterised the system in 2002 (a six hundreds euros gap between the North and the South).[27] In terms of national recognition, universities increasingly focused on their images. The annual number of press citations received from the local, national and international print media increased substantially over the last decade (by more than 200%). Northern universities were generally more frequently cited (704 press citations in 2012), especially in comparison to the universities located in the South (259 press citations in 2012). Furthermore, Table 1 shows that our parameter for competitors' proximity is constant for Northern universities, while it decreased by 5% in the Centre. However, the index indicated that universities in the South suffered to a lesser extent from competition with universities in close proximity over time (-10%).

[27] In regression analyses we rely on the ratio between universities' tuition fees and the GDP of the province of origin of students in order to consider the different market power of families across different areas in Italy.

Figure 2. Map of university competition
The sizes of the circles represent the level of competition to which each university is subjected.

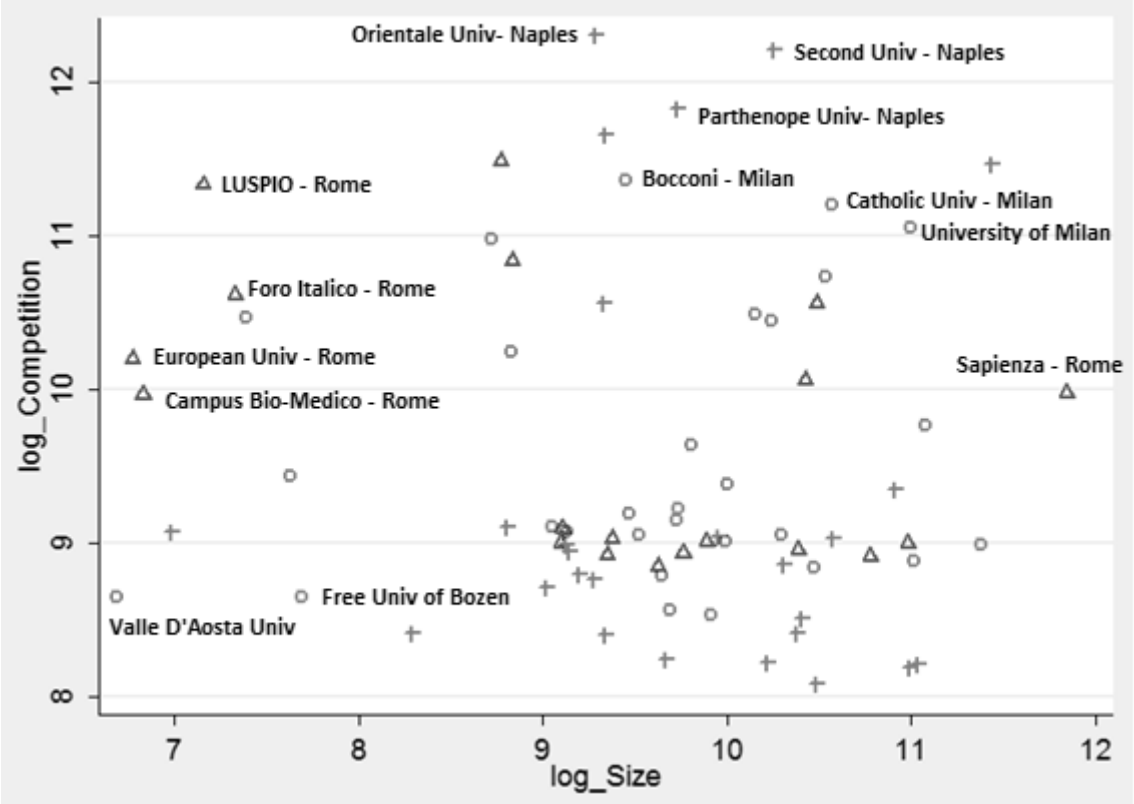
To understand how university competition is distributed at the national level, Figure 2 plots the average value of the log of the *Competitors' proximity index* over the last decade. Universities in the areas of Milan, Naples and Rome exhibit the highest levels of competition. In contrast, the competition among academic institutions is quite limited in the South and the Islands, and the latter are also characterised by geographic barriers.

Finally, we plot the log of the average competition among universities against log university size, measured by the average number of students in the period 2002-2012[28]. Circles represent universities in the North, triangles stand for those located in the Centre, while crosses indicate Southern universities. Three groups of universities are identifiable: 1) small universities, facing different levels of competition and medium-large sized universities facing 2) low and 3) high levels of competition. Among small universities, those in the Centre, mainly located in the area in and around Rome, were subject to greater competition, while those in the North tend to cover specific geographical markets with no other universities in close proximity, as in the case of the Valle D'Aosta University. The largest fraction of medium- and large-sized universities located in southern Italy is subject to low levels of competition. The only exception is those operating in the Naples

[28] We plot 74 universities excluding the *BRA - University of Gastronomic Sciences* (log of competition = 5.26; log of size = 8.92*)* to make the plot more readable.

area, which exhibits a high level of competition (e.g., Orientale University, Second University). On average, competition affected the medium and large universities located in the North to a greater extent than those in the Centre, where university markets are characterised by the same level of competition irrespective of the universities' size.

Figure 3. Scatter plot of university competition and university size
The figure plots the log of university competition against the log of university size. Circles represent universities in the North of Italy; triangles indicate universities in the Centre; and southern universities are identified by crosses.



5. Results

Table 2 reports the estimates of our competition destinations model for the population of Italian universities over the period 2002-2012. Model 1 tests Hypothesis 1 and presents the results of estimations performed using the entire population of universities. The coefficient of the *Competitors' proximity index* is negative and highly significant at the 1% level. Consistent with the literature on competition destinations models, this reveals the presence of strong competition forces among universities, which negatively affect the number of students that universities are consequently able to enrol. These findings are consistent with our expectations.

Table 2. University competition for students in Italy

This table reports the results of the PPML model estimated to examine the presence of competitive forces among Italian universities. The sample consists of 75 universities observed during the period 2002-2012. Model (1) considers all student flows towards Italian universities; Model (2) adjusts the *Competitors' proximity index* for the overlap in the universities' departments. The number of observations changes with respect to the student flows excluded by the different models. Each regression controls for time and province fixed effects. Standard errors are reported in brackets. ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

	(1)	(2)
Distance (province *j* - university *i*)	-1.903***	-1.511***
	(0.058)	(0.064)
Origin (Province features)		
Quality of life ranking	0.006	-0.012
	(0.008)	(0.007)
Value added per capita	-0.886***	-0.453**
	(0.136)	(0.192)
Student population	0.975***	0.435***
	(0.041)	(0.054)
Destination (Province and University features)		
Quality of life ranking	0.017	0.090**
	(0.034)	(0.045)
Value added per capita	1.789***	1.553***
	(0.219)	(0.235)
University size	0.827***	0.655***
	(0.044)	(0.044)
University teaching resources	0.162**	0.125**
	(0.079)	(0.055)
University legitimacy	0.022	0.033
	(0.025)	(0.027)
University's average tuition fee	0.527	0.503
	(0.663)	(0.522)
Competitors' proximity index	-0.242***	-0.087***
	(0.060)	(0.028)
Constant	-9.353***	-8.853***
	(1.723)	(2.541)
Observations	84,519	84,519
R-squared	0.887	0.517

Regarding the other variables included in the model, all those reporting significant coefficients have the predicted signs. The variables capturing the emission and the absorption capacity of origins and destinations (*Student population, University size*) are positive and highly significant. Accordingly, the value added per capita of the province in which the university of destination is located is positive and highly significant. The higher the expectation of students' future success in the labour market in more advance provincial economies, the higher the attractiveness of the universities located in those areas. Predictably, the greater the distance between the province of origin and a university, the lower the likelihood that students will choose that institution. This might be due to both social factors, such as the unfamiliarity of students with the culture of more distant places, and economic factors, such as the higher costs students incur in terms housing and food when far from home (DesJardins, Dundar, and Hendel 1999). Our findings also suggest that having a larger number of faculty members per student leads to greater learning opportunities for students, which are accorded substantial weight in students' decision-making processes. After scaling universities' fees with respect to the value added per capita of the students' province of origin, direct investment in higher education does not seem to affect the universities' attractiveness to students.

In Model 2, presented in Table 2, we repeat the analysis but consider the department overlap in the *Competitors' proximity index*. The empirical evidence again demonstrates the presence of competition for students among Italian universities in the period 2002-2012. While the index is still significant at the 1% level, the magnitude of the coefficient decreases relative to that observed in Model 1, from 0.242 to 0.087. With respect to the control variables, all coefficients take the expected signs, and the quality of life in the destination province becomes significant at the 5% level.

Table 3 reports the results of the PPML regression that includes the structural break in 2009 to evaluate whether the effects of competition have changed since the financial crisis (Hypothesis 2). Our findings indicate that the period after 2009 is negatively related to the overall attractiveness of universities to students throughout the higher education system. This corroborates the evidence that enrolments have significantly decreased following with the financial/economic crisis. More important, the interaction term (*Competitors' proximity index X Financial crisis*) is positive and highly

significant, suggesting that agglomeration forces have begun to characterise the Italian higher education system since 2009. Although the coefficient of the *Competitors' proximity index* still suggests that, on average, competition forces are present among universities, a dynamic transformation of their attractiveness to students has occurred. These results therefore confirm Hypothesis 2.

Table 3. The changing impact of university competition over time
This table reports the results of the PPML model estimated to examine the presence of competitive forces among Italian universities. The sample consists of 75 universities observed during the period 2002-2012. The analysis replaces the analysis of Model 1 in Table 2 in examining the structural break identified using the Chow breakpoint test. The interaction term between the *Competitors' proximity index* and the structural break in 2009 is also included. Each regression controls for time and province fixed effects. Standard errors are reported in brackets. ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

Distance (province *j* - university *i*)	-1.904***
	(0.058)
Origin (Province features)	
Quality of life ranking	0.022
	(0.034)
Value added per capita	-0.724***
	(0.117)
Student population	0.931***
	(0.047)
Destination (Province and University features)	
Quality of life ranking	0.007
	(0.008)
Value added per capita	1.787***
	(0.220)
University size	0.827***
	(0.044)
University teaching resources	0.162**
	(0.079)
University legitimacy	0.021
	(0.025)
University's average tuition fee	0.512
	(0.663)
Competitors' proximity index	-0.258***
	(0.060)
Financial crisis	-0.442***
	(0.146)
Competitors' proximity index X Financial crisis	0.046***
	(0.010)
Constant	-10.452***
	(1.842)
Observations	84,519
R-squared	0.887

Beginning in 2009, when the effects of the recession had begun to influence both the demand for and supply of higher education (Long 2013), a selective loss of students occurred. The decrease of student enrolments did not affect the university system homogenously. Universities that had already operated in more competitive environments were generally more prepared to strategically react than others, and consequently experienced the smallest declines in enrolment rates following the crisis. In particular, observing the change in the market share of enrolled students between 2007 and 2012, universities in close proximity to others performed better, holding all other factors determining attractiveness equal. In the areas characterised by higher levels of competition (Milan, Rome and Naples) universities increased their attractiveness over the last 4 years despite the ongoing decline in student enrolment at a system level. For example, considering the universities within a radius of 50 km from the centre of Milan, they, on average, increased their market share (e.g., Polytechnic University of Milan +0.5%, University of Milan +0.5%, Catholic University of the Sacred Heart +0.3%, University of Milan Bicocca +0.3%, University of Bergamo +0.1%). Conversely, the greatest decrease in market share occurred among those universities operating under the least competition, which are primarily located in the South (e.g., University of Palermo -1.2%, University of Lecce -0.7%, University of Catania -0.6%).

We argue that during periods characterised by lower levels of demand for higher education, families and students electing to spend on post-secondary education are more selective in choosing strategic university poles. The overall decline in well-being and economic stability associated with the decrease in incomes and, in some cases, the loss of employment leads families and students to make a more accurate selection. To the extent that making an investment in education has become more demanding, universities located in more competitive environments become more attractive being more equipped to offer greater income and employment opportunities to students after graduation.

6. Robustness checks

In this section, we report the results of additional analyses performed to check the robustness of our results. First, due to characteristics that differentiate private universities from public ones (Lach and Schankerman 2008; Minelli, Rebora, and Turri 2012), such

as the ability to select students, their greater freedom in selecting the tuition fees per student and their higher average faculty salaries, we perform a PPML regression when excluding such universities from our investigation. The results suggest that competition forces characterised public universities' attractiveness during the period 2002-2012 (Model 1, Table 4).

Table 4. Robustness checks

This table reports the results of the PPML gravity model estimated to examine the presence of competitive forces among Italian universities. The sample consists of 75 universities observed during the period 2002-2012. Model (1) excludes student flows toward private universities; Model (3) does not include student flows from selective courses (e.g., Architecture; Medicine and Surgery; and Veterinary Medicine). The number of observations changes with respect to the student flows excluded by the different models. Each regression controls for time and province fixed effects. Standard errors are reported in brackets. ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

	(1)	(2)
Distance (province *j* - university *i*)	-1.934***	-1.853***
	(0.057)	(0.055)
Origin (Province features)		
Quality of life ranking	0.006	-0.001
	(0.008)	(0.009)
Value added per capita	-0.860***	-0.855***
	(0.157)	(0.170)
Student population	1.003***	0.973***
	(0.040)	(0.039)
Destination (Province and University features)		
Quality of life ranking	0.026	0.042
	(0.033)	(0.036)
Value added per capita	1.664***	1.517***
	(0.231)	(0.226)
University size	0.798***	0.797***
	(0.058)	(0.041)
University teaching resources	0.171	0.072
	(0.171)	(0.060)
University legitimacy	0.029	0.006
	(0.024)	(0.024)
University's average tuition fee	1.131	1.156**
	(0.820)	(0.553)
Competitors' proximity index	-0.253***	-0.222***
	(0.068)	(0.057)
Constant	-7.900***	-7.392***
	(1.864)	(1.817)
Observations	70,826	83,188
R-squared	0.890	0.798

Second, we exclude the courses offered by universities characterised by a limited number of available places (e.g., Architecture; Medicine and Surgery; and Veterinary Medicine). Although the presence of such courses is only limited to certain departments and is recognised to be a marginal phenomenon in Italy (Rossi 2009), the dynamics underlining the universities' attractiveness to students might be different in these cases. Such departments impose different admissions standards. Although all Italian faculties were required by law (Ministerial Decree 270/2004 - art.6) to introduce entry tests with the sole objective of providing students with specific indications of abilities without invalidating their admission, courses with a limited number of available places require students to pass certain selective admission tests prior to enrolment. While the former permits admission regardless of the test score, the failure to achieve the score threshold in selective courses revokes student admission. Model 2, presented in Table 4, indicates that the coefficient of the *Competitors' proximity index* is negative and highly significant after excluding these types of courses. The only difference is that the average fee per student turns becomes significant. After excluding selective programmes, which account for small share of student flows, students are significantly attracted by universities with higher tuition fees. The cost to attend a university is perceived as a proxy for the quality of a university's services.

7. Conclusion

This paper examined the presence of university competition for students over the period 2002-2012 in the Italian higher education system. By using a competing destinations model, we first provided empirical evidence that universities have competed with one another to attract a larger number of students over the last decade. Our results are robust to different model specifications, namely those addressing the overlap of departments across different institutions, excluding private universities and limiting the analysis to non-selective courses. Second, our dynamic perspective allowed us to investigate the evolution of university competition over time. We found significant evidence that the recent financial crisis affected the students and families' selection of a university.

Universities in close proximity to others have been considered more attractive and are responsible for the development of clusters of higher education.

This paper highlights how university competition for students might impact the universities' attractiveness to students when the market for students changes due to external conditions. Specifically, in periods of high demand for post-secondary education, the presence of competitors in close proximity decreases the number of potential students that each university can enrol. However, the competitive environment in which a university operates can positively influence the number of students it might enrol during periods with scarce demand for higher education. As the choice of a university is guided by an investment decision, after the recent financial crisis it has become increasingly important to not only to attend university but also to attend a university operating in a competitive environment, where the institution's racing behaviour is expected to increase its quality over time.

The results of our paper have important implications for understandings of the migration of highly skilled human capital and its associated positive externalities. To the extent that university competition might be responsible for the attraction of students towards specific areas, this might affect, *ceteris paribus*, the distribution of human capital in different regions, thereby affecting their growth and competitiveness over time. A more competitive environment might lead universities to offer students better services, characterised by higher quality and additional interactions with industry during their educational careers. Departing from recent contributions seeking to study the evolving role of universities as "catalysts" for local development (e.g., Audretsch 2013) and the impact of students' education in affecting the growth of regions (Winters 2011; Bauer, Schweitzer, and Shane 2012), addressing the economic impact of the competition among universities might be a promising avenue for future research.

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Appendix A. Correlation matrix.

The table reports correlation coefficients among the independent variables employed in the regressions. (*O*) indicates the variables for the origin, while (*D*) stands for the variables for the destination. Significant correlations at less than 1% are identified with an *.

	Variables	1	2	3	4	5	6	7	8	9	10	11
1	Distance (*O-D*)	1										
2	Quality of life ranking (*O*)	-0.0202*	1									
3	Value added per capita (*O*)	-0.2373*	0.2658*	1								
4	Student population (*O*)	0.0021	-0.0614*	0.0119*	1							
5	Quality of life ranking (*D*)	-0.0430*	-0.0172*	-0.0081	0.0057	1						
6	Value added per capita (*D*)	-0.1835*	0.0174*	0.0273*	-0.0086	0.3381*	1					
7	University size (*D*)	0.0011	-0.0043	-0.0032	0.0023	0.0228*	0.0269*	1				
8	University teaching resources (*D*)	-0.0385*	0.0019	0.0017	-0.0004	0.0125*	0.1446*	-0.1005*	1			
9	University legitimacy (*D*)	-0.0538*	-0.0453*	-0.0260*	0.0262*	0.1700*	0.2035*	0.5262*	-0.0472*	1		
10	University student fees (*D*)	-0.0735*	0.0134*	0.0205*	-0.0085	0.1153*	0.5638*	-0.2691*	0.2089*	-0.0377*	1	
11	Competitors' proximity index (*D*)	-0.0424*	-0.0027	-0.0029	0.0014	-0.0341*	-0.0432*	-0.0193*	0.1121*	-0.0741*	0.1888*	1

CHAPTER 4. PhD funding as a determinant of PhD and career research performance

Submitted to *Research Policy*

Abstract

This article focuses on doctoral grants' effects on research performance both during the degree and throughout researchers' careers as measured through publications and citations. This analysis draws from a representative sample of researchers holding a doctorate based in Portugal and finds that those funded by grants during the PhD perform better than do self-funded ones and that different PhD funding sources produce different outcomes. We also find that PhD funding schemes that privilege long-term PhD funding stability (i.e. PhD grants) positively affect research performance during the PhD and throughout the career, while those awarded research project grants during their PhD do not benefit from this effect. We argue that the latter funding scheme has more limited effects because of the constraints typical of early-stage researchers involved in research project dynamics.

Keywords: PhD funding; Research productivity; Research visibility; PhD Research performance; Career research performance; Propensity score matching; Portugal

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1. Introduction

The PhD is considered the *de facto* starting point of academic careers and a requirement for everyone engaged in independent research (Sinclair et al., 2013; Lee et al. 2010). Driven by increasing investments in intangibles, the number of PhDs grew annually by nearly 40% in OECD countries between 1998 and 2008 (Cyranoski et al., 2011). As the number of doctorates has grown, the nature of the PhD has changed, becoming more attuned to dynamic knowledge-driven societies (Jackson, 2013). Due to the mounting pressure on PhDs to publish, the number of doctoral students who publish is increasing. Pinheiro et al. (2014) show that between 70% and 90% of US doctorates in the science, technology, engineering, and mathematics (STEM) fields published before concluding their PhD in the 2000s compared to between 40% and 80% in the 1990s.

The trend toward publishing during the PhD has been leading PhD students to make greater contributions to institutional, national, and international bodies of knowledge. A study on research output in the Canadian province of Québec found that PhD students participated in a third of all publication output between 2000 and 2007 (Larivière, 2012). Some scholars argue that research undertaken during the PhD can contribute more effectively to address global challenges, and that it is necessary to better understand PhDs' contribution to scientific development (Walker et al., 2006). This includes a better understanding of PhD funding mechanisms, as the funding of research grants (particularly competitive) are known to impact researchers' decision making, behaviour, and research output throughout their careers (Bloch et al., 2014; Feeney and Welch, 2014; Grimpe, 2012; Benavente et al., 2012; Jacob and Lefgren, 2011a, b; Kelchtermans and Veugelers, 2011; Ubfal and Maffioli, 2011; Arora and Gambardella, 2010; Bozeman and Gaughan, 2007; Gaughan and Robin 2004).

The funding of PhDs is also a critical issue for policymakers, given the accelerated competition in the global knowledge drive. The Salzburg principles on doctoral education stress that appropriate funding levels are key to the quality and successful completion of the PhD (EUA, 2010). More U.S. universities are offering multiple-year funding to their doctoral students (Nerad, 2006), and university associations in Europe have underlined the need for PhD funding support (LERU, 2014). These policy recommendations and funding trends are supported by the literature on the relationship between funding and the successful completion (e.g. Wright and Cochrane, 2000) and duration of doctorates (Wao,

2010). Similarly, empirical studies on how publishing during the PhD affects researchers' careers suggest a positive effect (e.g. Pinheiro et al., 2014). However, the effect of PhD funding sources on research performance (including research productivity and visibility) during the PhD and throughout the career remains underexplored.

Given the importance of this issue to the development of science and scientific systems, this article examines whether PhD funding sources impact research productivity and visibility (as measured by citations; see Inanc and Tuncer, 2011) during the PhD and throughout the researchers' careers. It draws on a representative sample of researchers holding PhDs resident in Portugal in 2009. The data were obtained through a survey designed and implemented by the statistics office of the Ministry of Science and Education for the OECD Careers of Doctorate Holders project. A conditional difference-in-differences (DID) approach was used to assess whether the impact of PhD funding sources has a significant impact on researchers' publication performance during their PhD and their careers. A sample of researchers awarded a grant was matched with a sample of researchers who had received no funding. The analysis evaluated doctoral grants' impact on research performance as well as how two competitive grants—one providing greater funding stability (the *PhD grant*) and the other less (the *research project grant*)—affected research performance both during the PhD and afterwards (i.e. the post-PhD career, assuming it begins immediately after the conclusion of the PhD; Sinclair et al., 2013).

The rest of this paper is organized as follows. The next section reviews the literature on the relationship between funding and research performance, and between funding and PhD outcomes. Section 3 describes the study's data, variables, and methodology. The results are presented in Section 4. The paper concludes in Section 5 by presenting the key results and implications for science policy and possible avenues of future research.

2. The relevance of funding for scientific performance during doctoral training

Competitive public funding for research is considered crucial for increasing scientific output in knowledge-based societies (Arora and Gambardella, 2010). Funding for research has been found to positively affect research productivity at systemic and

institutional levels. The analysis of the Chilean National Science and Technology Research Fund in Benavente et al. (2012) shows a positive relationship between public research funding and publication output. The relationship between research funding and citations is also found to be positive in analyses of Argentina's Fund for Scientific and Technologic Research and the United States National Institute of Health programs (Chudnovsky et al., 2008; Jacob and Lefgren, 2011a, b).

Other recent studies show that research grants together with public funds substantially increase research collaborations (Bozeman and Gaughan, 2011; Ubfal and Maffioli, 2011; Defazio et al., 2009), which in turn positively influence research productivity (Lee and Bozeman, 2005). Competitive research grants have also been recognized to exert a significant influence over researchers' careers. For example, research grants awarded by the Danish Agency for Science, Technology, and Innovation were found to create conditions that enhanced academics' chances of career advancement, up to full professorship (Bloch et al., 2014). However, the research outcomes of projects funded by the U.S. National Science Foundation (NSF) were found to be heterogeneous among team members, varying significantly according to the member's role and sex (Feeney and Welch, 2014).

The literature further indicates that different research funding mechanisms have differing effects on scientific performance. Kelchtermans and Veugelers (2011) analysed KU Leuven's 1,036 exact science and biomedicine researchers and found that project grants aimed at fostering research performance impacts on research groups differed from those projects aimed at fostering fundamental research and setting new research foci in terms of scientific productivity and visibility. Although both positively impacted research output, the former funding mechanism most strongly affected the publication output of early career researchers, while the latter mechanism showed a consistently positive effect on the visibility of all researchers in terms of citations.

The studies mentioned above suggest that systemic, institutional, and individual funding for science is important to scientific output and visibility; however, they also suggest that funding mechanisms differ in their impact. The empirical evidence about doctoral grants demonstrates that funding for doctoral grants impacts both the completion rate and duration of PhD degrees but also that the nature of the funding sources determines the impact. Using data from 681 successful doctoral students at the University of

Minnesota, Jones-White and Glushko (2013) found that different PhD funding sources had varied impacts on completion. Students supported by institutional grants or teaching assistantships faced a greater completion hazard than did those who were not. Those using loans to fund their PhD faced a lower completion hazard. Wright and Cochrane (2000) show that PhD students in the UK supported by Research Council funding were more likely to submit successfully (66%) than those supported by other funding sources (58%). Differences among PhD funding sources were also found to impact time to graduation. A seminal study by Ehrenberg and Mavros (1995) using an institutional dataset of PhD students at the University of Cornell found that in the field of mathematics those supported by research grants took 4.54 years to finish their degree, while those supported by teaching assistantships took 4.82, and those with other support took 4.83. The authors found different variances in other disciplines.

Notwithstanding these analyses, the importance of PhD funding types as determinants of scientific productivity and visibility during and after the PhD is still relatively unexplored. This is somewhat surprising, particularly given the view that PhD funding and its sources can impact graduates' professional plans and outcomes (Mangematin, 2000). It is reasonable to assume that PhD funding may signal what doctoral students will achieve. Recent evidence on early-career researchers shows that public funding for scientific career development impacts researchers most strongly in the early stage of their careers (Arora and Gambardella, 2010). Postdoctoral grants, for example, were found to increase the number of articles researchers published in the 10 years following their award (Jacob and Lefgren, 2011a). Another study by the same authors shows that postdoctoral grants increased the number of publications and citations during the five years following grant application by about 20% (Jacob and Lefgren, 2011b).

We found only one study on the relationship between PhD funding sources and research performance. Pion (2001) compared the post-doctorate publications of PhDs supported by the National Research Service Award (NSRA), the National Institutes of Health (NIH), and non-NIH training institutions in the U.S. The author found the average number of post-PhD publications and citations per publication to be significantly higher for those who had benefited from a NRSA grant than for the other two groups. Pion (2001) suggests that different PhD funding sources affect post-PhD researchers' publication

performance differently but focuses solely on biomedicine. Our study applies a broader scope by considering the effects of PhD funding in relation to publications and visibility for all fields of knowledge within a national scientific system (i.e. Portugal's).

3. Data and methods

3.1. Data and sources

This analysis uses the 2009 Careers of Doctorate Holders (CDH) dataset drawn from a survey conducted by the Portuguese Ministry of Science and Education. The data concern researchers who had completed their PhDs up to 2009. The sample was selected through stratified random sampling according to the field of knowledge, gender, and age of all doctorate holders residing in Portugal on December 31, 2009. Through a representative sample methodology, a group of respondents proportional to the size of the strata was randomly selected from each strata (see Marôco, 2011). The selected respondents were surveyed online or using hard copies when necessary. The dataset contains information on 4,095 PhDs' socio-demographics, sources of PhD financial support, field of science, educational and professional paths, and international mobility.

The survey also asked PhDs to list their publications and other scholarly work to facilitate accurate identification through the publication data featured on the Thomson Reuters Web of Science (WoS). Publications published until 2012 were considered to account for publications' preparation time and delays resulting from the scholarly review process (see Björk and Solomon, 2013). Then, a two-step process was used to validate authors' names, minimizing the issues associated with homonyms or namesakes. Reconciliation algorithms were used (following Maali et al., 2011), followed by manual validation. At the end of this process, 26,165 publications (articles only) and 861,014 associated citations were identified. Given the growing importance of international scientific collaboration, we also examined the research performance of publications co-authored with peers based abroad by separately classifying co-authored publications where at least one author of which is based outside Portugal. This exercise led to the identification of 11,112 publications and an associated 385,159 citations.

3.2. Methodology

This paper investigates the impact of PhD funding sources on the publication performance of PhD holders' degrees and careers. As doctoral grants are allocated through a competitive process, funding allocation might be correlated to unobserved researcher characteristics such as skills and ability, which are also known to be determinants of research performance. A conditional difference-in-differences (DID) method is used to address the potential endogeneity issue (e.g. Bloch et al., 2014, Aerts and Schmidt, 2008). This procedure combines the benefits of the simple DID approach with those of propensity score matching (PSM) to provide more reliable results (Blundell and Dias, 2002). Conditional DID based on non-parametric matching is an effective tool for controlling the selection of both the observable and unobservable characteristics (e.g. Heckman et al., 1998; Smith and Todd, 2005).

In the conditional DID, nearest-neighbour matching is first used as a PSM. Through a probit regression, the probability of receiving a doctoral grant (i.e. being treated) is estimated to obtain propensity scores. The matching is performed with replacements to avoid biasing the estimates through the observations' sort order and sample size. A common support area is also analysed: we exclude researchers with an extremely high or low probability of receiving a doctoral grant to ensure that the characteristics observed in the treatment group can be observed in the control group as well. Second, we analyse the effect of receiving doctoral grants on research performance during and after the PhD by estimating the average treatment effect of treated (ATT) on the matched sample. At this stage, the analysis focuses on the effect of the two doctoral grant sources, the *PhD grant* and the *research project grant*, regressed in relation to research performance through the estimation of a set of multivariate regressions (OLS models) with robust standard errors. Consistent with the conditional DID approach, these regressions include three sets of variables: 1) the variables used in the matching procedure, 2) a dummy variable identifying researchers awarded PhD grants, and 3) other variables that might influence the treatment effects. Multicollinearity tests dismissed the potential for problems since none of the mean variance inflation factors exceeded 1.6, which is below the typical cut-off of 10 (see Kutner et al., 2004).

3.3 Variables

3.3.1 Dependent variables

The measures of research performance used as dependent variables in this study are researcher productivity and visibility (Inanc and Tuncer, 2011) during the PhD and following its conclusion (i.e. the researcher's career). This approach follows the literature in addressing the well-known issues associated with differences among lengths of career (Dietz and Bozeman, 2005; Fukuzawa, 2013).

Research productivity

Research productivity is measured as the cumulative number of publications authored by a researcher during the doctorate divided by the number of years elapsed from the beginning of the degree to its conclusion (*PhD productivity*). *Career productivity* is the number of publications published after the PhD divided by the number of years elapsed from the end of the PhD to December 31, 2012. *Productivity with peers abroad during PhD* and *Career productivity with peers abroad* are measured the same way but only for co-authored publications, one of whose authors is based outside Portugal. The former variable measures research productivity during the PhD, while the latter measure research productivity evidenced after its conclusion.

Research visibility

Research visibility represents the average number of annual citations per publication. As for research productivity, the average number of citations is divided by the number of years within the observation period. *PhD visibility* is the average number of citations per publication published during the PhD divided by the number of years between the publication date and December 31, 2012. *Career visibility* is the average number of citations per publication appearing after the PhD divided by the number of years between the PhD's completion and December 31, 2012. *Visibility of publications with peers abroad during PhD* and *Career visibility of publications with peers abroad* are measured as the average number of citations received during each period by co-authored publications one of whose authors is based outside Portugal. The former variable refers to citations of publications published during the PhD, while the latter two refer to citations of publications published after its completion.

3.3.2 Independent variables

The literature claims that the main funding sources for doctoral candidates are doctoral grants, that take the form of either *PhD grants* or *research project grants* (e.g. Visser et al., 2007). They are the types of doctoral grants available in Portugal, and are different in several ways.

PhD grants tend to be awarded by national funding agencies through public competitive research funds. Candidates submit proposals directly to the funding agencies; these are evaluated by committees, which recommend some of the PhD research proposals for funding. In Portugal, the national competitive research fund scheme is coordinated by the Portuguese Foundation for Science and Technology (FCT) through an annual call for PhD grant requests. Grants are awarded for one year, with the possibility of annual renewal upon recommendation from the PhD mentor and the submission of the candidate's own assessment of the work in progress. The grants are renewable for up to four years and cannot be awarded for a period of fewer than three consecutive months. The grants require exclusivity (the PhD student cannot take any other job or earn additional income) to ensure that the doctoral students are fully dedicated to completing the proposed PhD research agenda. Doctoral degree grantees are entitled to the annual co-payment for registration, tuition, and other fees. The Portuguese model is similar to Holland's AIO (*Assistent In Opleiding*) model (see van Ours and Ridder, 2003). In the regressions, we identify those funded by a *PhD grant* through a dummy variable (with *PhD grant* equalling 1).

Research project grants are given to research assistants through a university or research institute to assist in research projects. The fellows are usually hired based on a decision of the project's principal investigator or an evaluating committee associated with the project. The candidate selection process is a competitive one based on the skills deemed necessary for the successful conclusion of the research project in question. The research assistants are hired based on the skillsets required or deemed important for project tasks. Grant durations vary according to the duration of the project and/or the specific activities the grantees have been hired to develop. *Research project grants* offer the opportunity to initiate doctoral studies, often on topics related to the research project. PhD students funded by projects may integrate more than one project during their degree, implying that candidates funded by projects experience more funding uncertainty, greater pressure to

produce results (often related to the project goals and not necessarily to the PhD's objectives), and a stronger need to proactively seek funding. A dummy variable equal to 1 identifies doctorate holders who were funded by *research project grants* during their degree.

No grant funding is the baseline variable indicating students who do not receive any sort of public, systemic, or institutional funding but rely on self-funding, usually derived from a salary, personal loans, and/or the student's savings.

3.3.3 Control variables

Our analysis includes known controls of research productivity such as nationality, gender, age (at the beginning of the PhD), and fields of science. Additional variables of interest were included based on career stage (i.e. pre-PhD, during the PhD, after the PhD). The control variables are presented individually below for each stage (see Table 1).

In the first stage (pre-PhD), the probability of receiving a grant is modelled upon the following covariates in order to set a valid control group to reduce selection bias:

Time to PhD: The longer the period between the previous degree attained and the start of the PhD, the higher the probability that the students had worked outside academia before starting the degree. *Time to PhD* is expected to have a negative effect on the probability of being awarded a grant. The best and most motivated doctoral students usually start their PhD immediately after completing their previous degree since they tend to be highly focused on an academic/research career (Stirati and Cesaratto, 1995).

Graduated from a prestigious university: Considering the relevance of positional goods in research and academia (Marginson, 2006), the reputation of the university the student graduated from before starting the PhD is expected to increase the probability of receiving a grant. Prestigious universities are highly selective at entry level, and admitted students have the opportunity to study in research-oriented environments. Prestigious universities are defined as those ranked in the first edition of the 2003 ARWU (Academic Ranking of World Universities).

Field change to the PhD: Changing the scholarly field from that of the previous degree attained may affect the probability of receiving a grant. A diverse educational path may,

ceteris paribus, increase the probability of receiving a grant because of the candidate's acquisition of multidisciplinary knowledge and ability to draw on this knowledge to tackle complex and uncertain problems (typically focused during the PhD). However, changing research fields may discourage awards because of the disciplinary mindset dominating national funding agencies' evaluation committees and parts of academia (Pellmar and Eisenberg, 2000).

More degrees before the PhD: Attaining more than one degree before starting the PhD suggests greater academic experience, knowledge, and maturity, which may provide a competitive edge in grant awards.

In the second stage (during and after the PhD), the following controls are considered to assess the impact of PhD funding on the degree and career research performance:

PhD in Portugal: The location of the PhD using a dummy variable equal to 1 if the PhD was performed in Portugal, and 0 otherwise.

PhD in oldest Portuguese universities: Since the prestige of a university affects scientific productivity (e.g. Buchmueller et al., 1999), this variable is used to account for PhDs performed at Portugal's four oldest and most research-intensive universities: University of Lisbon, University of Porto, University of Coimbra, and Technical University of Lisbon (see Heitor et al., 2014).

International mobility: Studies suggest that international mobility is positively correlated to research performance (e.g. Kato and Ando, 2013; Jonkers and Tijssen, 2008). International propensity is proxied by the number of international mobility spells taken by the researcher (*Nr. of international moves*) and by the researcher's international network. The latter variable is measured as the researcher's average number of international affiliation co-authorships (*International network*).

Job mobility: A higher number of job changes (*Nr. of job changes*) positively impacts career information exchange, collaboration, and research productivity (Horta and Yonezawa, 2013; Dietz and Bozeman, 2005). Researchers currently working in academia are also identified as such (*Working in academia*).

Research field mobility: The ability to publish in several scientific fields implies the possibility of bringing multiple perspectives to bear on a research problem and coupling

knowledge across disciplinary boundaries (van Rijnsoever and Hessels, 2011). Thus, researchers who publish in more than one WoS research field are identified through a dummy variable equal to 1.

Table 1. Variables description

Variables	*Description*
Dependent variables during the PhD	
Productivity PhD	Number of publications authored during the doctorate divided by the number of years from the beginning to the conclusion of the PhD.
Visibility PhD	The average number of citations per year received by publications published during the PhD.
Productivity with peers abroad during PhD	Number of publications co-authored during the doctorate with at least one author based outside Portugal, divided by the number of years from the beginning to the conclusion of the PhD.
Visibility of publications with peers abroad during PhD	The average number of citations per year received by publications published during the PhD co-authored with at least one author based outside Portugal.
Dependent variables after the PhD	
Career productivity	Number of publications authored after the PhD divided by the number of years elapsed from the end of the PhD to December 31, 2012 (after PhD).
Career visibility	The average number of citations per year received by publications published during the career (after PhD).
Career productivity with peers abroad	Number of publications co-authored during the career (after PhD) with at least one author based outside Portugal, divided by the number of years from the beginning to the conclusion of the PhD.
Career visibility of publications with peers abroad	The average number of citations per year received by publications co-authored during the career (after PhD) with at least one author based outside Portugal.
Independent variables	
PhD grant	Dummy variable equal to 1 if the doctorate holders was funded by a PhD grant.
Research project grant	Dummy variable equal to 1 if the doctorate holders was funded by a research project grant.
Personal control variables	
Nationality	Dummy variable equal to 1 if the researcher is Portuguese, 0 otherwise.
Gender (Male =1)	Dummy variable equal to 1 if the researcher is a male, 0 otherwise.
Age at PhD	Number of years elapsed between the year of birth and the beginning of the PhD.

Control variables pre-PhD	
Field change to the PhD	Dummy variable equal to 1 if the researcher changed fields between the last degree attained and the PhD.
Graduated from a prestigious university	Dummy variable equal to 1 if the researcher graduated from a university included in the 2003 ARWU ranking.
Time to PhD	Number of years elapsed between the previous degree attained and the start of the PhD.
More degrees before PhD	Dummy variable equal to 1 if the researcher attained more than one degree before the PhD.
Field of science	Six dummy variables identifying the field of science before the PhD (i.e. Agriculture, Engineering and Technology, Natural Sciences, Medical Sciences, Social Sciences, Humanities).
Control variables during and after the PhD (career)	
Years after PhD	Number of years elapsed from the end of the PhD to December 31, 2009 (after PhD).
Number of international moves	The number of scholarly/academic/research visits lasting a minimum of three months to another country.
Number of job changes	Number of job changes after the PhD.
Publications in different fields	Dummy variable equal to 1 if the researcher published in more than one Web of Science research field (e.g. Acoustic, Biology, Economics) during the career.
Working in academia	Dummy variable equal to 1 if the researcher works in academia
International network	The average number of international affiliation co-authorships (co-authored publications with at least one author based outside Portugal) per researcher during the career (after PhD).
PhD in Portugal	Dummy variable equal to 1 if the researcher received the PhD in Portugal, 0 otherwise.
PhD at oldest Portuguese universities	Dummy variable equal to 1 if the researcher received the PhD from one of the four oldest universities in Portugal (i.e. University of Lisbon, University of Porto, University of Coimbra, or Technical University of Lisbon).

3.4 Descriptive statistics

Table 2 reports the summary statistics for the researchers, who either received a grant to support their PhD study or did not. The major difference between the two is the higher age on average at which the former began their PhD (41 years). Furthermore, the period between the end of their previous degree and the start of their PhD (6 years) is almost twice as long (3.16 vs. 5.61), they are less internationally mobile during their career (0.49 vs. 0.18) and publish less often in collaboration with peers based abroad (0.22 vs. 0.12). Their research performance is lower than that of those awarded with a grant during the PhD in terms of both research productivity (0.19 vs. 0.09) and visibility (1.30 vs. 0.54). The same holds true for productivity during their career (0.74 vs. 0.37) and research visibility (2.41 vs. 1.26). The research performance difference remains considerable when considering publications co-authored with peers based abroad and the visibility attained by these publications both during and after the PhD. Researchers not awarded a grant also publish less in different fields of knowledge (0.30 vs. 0.20).

Although statistically different, some of the variables have similar values: nationality (the vast majority are Portuguese), gender balance (with slightly more male than female researchers in both groups), field change to PhD, and working in academia. Both groups have similar percentages of graduates from prestigious universities before the PhD, numbers of degrees before the PhD, career years, and are also mostly immobile throughout their careers (with 0.35 vs. 0.32 job changes), consistent with what studies on the Portuguese science and technology system (Heitor et al., 2014) have found.

Table 2. Summary statistics

Variables	*Researchers awarded a doctoral grant*	*Researchers not awarded a doctoral grant*
Dependent variables during the PhD		
Productivity PhD	0.194***	0.087
Visibility PhD	1.299***	0.544
Productivity with peers abroad during PhD	0.096***	0.036
Visibility of publications with peers abroad during PhD	0.913***	0.271
Dependent variables after the PhD		
Career productivity	0.740***	0.373
Career visibility	2.409***	1.259
Career productivity with peers abroad	0.220***	0.122
Career visibility of publications with peers abroad	1.762***	0.817
Personal control variables		
Nationality (Portuguese =1)	0.941***	0.969
Gender (Male =1)	0.523***	0.584
Age at PhD	35.374***	40.716
Pre-PhD control variables		
Field change to the PhD	0.190***	0.155
Graduated in a prestigious universities	0.253	0.256
Time to PhD	3.156***	5.613
More degrees before the PhD	0.334	0.324
Field of science		
Agriculture	0.067**	0.049
Engineering and technology	0.272***	0.229
Natural sciences	0.267***	0.189
Medical sciences	0.099	0.115
Social sciences	0.196***	0.263
Humanities	0.098***	0.156
After-PhD control variables		
Years after the PhD	10.177***	10.962
Number of international moves	0.487***	0.184
Number of job changes	0.352	0.316
Publications in different fields	0.297***	0.204
Working in the academia	0.798***	0.884
International network	0.486***	0.275
PhD in Portugal	0.616***	0.842
PhD in a oldest Portuguese universities	0.348***	0.502

***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively.

4. Results

4.1. Propensity score matching

Before analysing the impact of PhD funding sources on publication and visibility performance during the PhD and researchers' careers, a probit analysis is performed to estimate the probability of receiving a doctoral grant during the PhD, as suggested by the PSM approach (at this stage, we evaluate *PhD grant* and *research project grants* jointly). Table 3 shows the marginal effects of this analysis. The younger the student is at the beginning of the PhD, the higher the possibility of receiving a grant to support the doctorate; this suggests that funding is usually given to those students who start (or seek to start) their PhD soon after the previous degree has been received. This is corroborated by the negative impact the time to the PhD has on funding. Our results also suggest that receiving a doctoral grant is determined by gender: males have a lower probability of being awarded a grant than do females. Nationality also plays a role: Portuguese students are less likely to receive funding (consistent with Portugal's science policy of fostering the internationalization of its scientific and academic system; Heitor et al., 2014).

Table 3. Marginal effects estimated from Probit regressions for the likelihood of receiving PhD funding

Probit regression	*Awarded a doctoral grant*
	(1)
Age at PhD	-0.020***
	(0.001)
Gender (Male=1)	-0.067***
	(0.016)
Nationality (Portuguese=1)	-0.108***
	(0.041)
Field change to the PhD	0.062***
	(0.022)
Graduated in a prestigious university	0.027
	(0.019)
Time to PhD	-0.012***
	(0.002)
More degrees before the PhD	-0.003
	(0.018)
Agriculture	0.141***
	(0.042)
Engineering and technology	0.012
	(0.029)
Natural sciences	0.025
	(0.030)
Medical sciences	0.032
	(0.035)
Social sciences	0.008
	(0.028)
Constant	2.142***
	(0.178)
Observations	4,095
Pseudo R-squared	0.106

***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively; Standard errors are denoted in parentheses. Humanities is the reference group with respect to fields.

The PSM analysis leads to a matched sample of 2,488 researchers. The matching of an initial sample of 4,095 Portuguese PhD holders produces a matched sample of 1,679 PhD holders who were awarded a doctoral grant and 809 who were not. Table 4 reports the means of the variables considered in Table 3 after the PSM and tested the quality of the matching procedure. The two groups of researchers are not characterized by systematic differences in terms of the descriptive statistics reported in Table 2. Their propensity scores are the same (0.494). In the t-test, we fail to reject the null hypothesis that the mean between the treatment and control groups is equal for all the variables considered. Following Yang et al. (2012), the matching procedure effectiveness is further tested by estimating the bias reduction and the pseudo-R-squared in the matching process. The bias is significantly reduced after the matching process (from an average value of 18.4 to 4.1), and the pseudo-R-squared of the propensity scores becomes closer to zero (0.004). These statistics confirm the validity of our matching procedure.

Table 4. Matching covariates

Variables	*Researchers awarded a doctoral grant*	*Researchers not awarded a doctoral grant*	*P-value*
Propensity Score	0.494	0.494	0.944
Nationality	0.918	0.899	0.280
Gender (Male =1)	0.523	0.503	0.255
Age at PhD	35.390	35.406	0.946
Field change to the PhD	0.227	0.208	0.472
Graduated in a prestigious universities	0.256	0.270	0.367
Time to PhD	3.160	3.363	0.162
More degrees before the PhD	0.334	0.316	0.239
Agriculture	0.067	0.067	0.945
Engineering and technology	0.273	0.256	0.273
Natural sciences	0.267	0.294	0.091
Medical sciences	0.099	0.094	0.598
Social sciences	0.197	0.179	0.185
Humanities	0.098	0.111	0.214

4.2 The impact of grants on PhD and career research performance

Based on the matched sample, the analysis first assesses the effect of doctoral grants on researchers' PhD and career research performance by calculating the ATT. Table 5 shows the means for our measures of research performance. At the PhD level, the research productivity of researchers awarded a grant is significantly higher than that of researchers

not awarded a grant. This also holds true concerning research productivity co-authored with peers based abroad. Researchers awarded a grant published 0.06 (0.19 vs. 0.13) more publications per year during the doctorate and co-authored 0.03 (0.10 vs. 0.07) more publications with researchers based in other countries. The visibility of researchers awarded a doctoral grant is also higher in both cases (i.e. PhD visibility and PhD visibility of publications co-authored with peers based abroad).

For career-level performance, both the productivity and visibility of researchers awarded a doctoral grant is higher in all measures of research performance. The larger difference concerns publication visibility, differing by 0.84 (2.41 vs. 1.57) citations per paper per year. The difference is also substantial concerning citations to publications co-authored with researchers based abroad (0.74). These results indicate that research performance differs between those awarded and not awarded a doctoral grant; this difference is not limited to research performance during the doctorate but extends throughout the career. This result suggests that the impact of doctoral grants awarded to support PhD studies extends beyond the duration of the PhD to encompass the researchers' careers.

Table 5. Average Treatment effects on the Treated

Variables	*Researchers awarded a doctoral grant*	*Researchers not awarded a doctoral grant*	*ATT*	*S.E.*
Research performance during the PhD				
PhD productivity	0.194	0.133	0.061***	0.02
PhD visibility	1.299	0.690	0.608***	0.12
Productivity with peers abroad during PhD	0.096	0.066	0.026**	0.01
Visibility of publications with peers abroad during PhD	0.913	0.369	0.543***	0.09
Research performance during the career				
Career productivity	0.740	0.613	0.105**	0.62
Career visibility	2.409	1.572	0.838***	0.16
Career productivity with peers abroad	0.220	0.209	0.012	0.03
Career visibility of publications with peers abroad	1.762	1.024	0.738***	0.13

***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively.

Since the literature suggests that diverse R&D funding mechanisms tend to lead to varied research impacts (e.g. Kelchtermans and Veugelers 2011), we assess the potentially differing impacts of dissimilar doctoral grants awarded to support PhD studies. The grants awarded to support the PhD are disaggregated into *PhD grants* and *research project grants* and analysed through a multivariate regression framework using the matched sample.

The results of Table 6 show that a *PhD grant* significantly increases the research performance of doctorate students during the PhD both in terms of productivity (Model 1) and visibility (Model 2). Those who completed a PhD supported by a *PhD grant* had 28% more publications per year and 46% more yearly citations per publication than did their peers without grant funding. Similar results are seen concerning the relationship between *PhD grants* and the number of publications co-authored with peers abroad and the citations awarded to them (Models 3 and 4). Being funded by a *PhD grant* increases the number of publications co-authored with peers based abroad by 37% per year during the PhD over the number produced by those without grant funding. The average citations for publications published with peers based abroad during the PhD by those awarded a *PhD grant* is also 88% higher than for those who financed their PhD without grants. No statistically significant differences are found in terms of research performance (i.e. productivity and visibility in all models) during the PhD between those benefiting from a *research project grant* and those funded by their own resources.

Table 6. PhD funding as a determinant of PhD research performance

OLS regression	*PhD productivity*	*PhD visibility*	*Productivity with peers abroad during PhD*	*Visibility of publications with peers abroad during PhD*
	(1)	(2)	(3)	(4)
Nationality (Portuguese = 1)	-0.050	0.114	-0.073	0.052
	(0.066)	(0.218)	(0.062)	(0.208)
Age at PhD	-0.009***	-0.090***	-0.004***	-0.064***
	(0.001)	(0.006)	(0.001)	(0.005)
Gender (Male = 1)	0.014	-0.120	0.013	0.055
	(0.018)	(0.105)	(0.012)	(0.093)
PhD in Portugal	0.032	0.439***	0.019	0.272**
	(0.023)	(0.122)	(0.019)	(0.113)
PhD in oldest Portuguese universities	0.037*	0.106	-0.027*	-0.083
	(0.022)	(0.140)	(0.016)	(0.125)
Field change to the PhD	0.031	0.064	0.037*	0.067
	(0.027)	(0.129)	(0.021)	(0.119)
Graduated in a prestigious university	-0.037**	0.073	-0.010	0.163
	(0.016)	(0.110)	(0.011)	(0.100)
Time to PhD	0.004**	0.033***	0.002	0.021**
	(0.002)	(0.011)	(0.001)	(0.009)
More degrees before the PhD	-0.012	-0.031	-0.008	-0.188**
	(0.019)	(0.114)	(0.014)	(0.093)
Agriculture	0.144***	1.047***	0.104***	0.836***
	(0.043)	(0.264)	(0.034)	(0.265)
Engineering and technology	0.135***	0.691***	0.048***	0.331***
	(0.020)	(0.122)	(0.014)	(0.100)
Natural sciences	0.215***	1.225***	0.121***	0.808***
	(0.020)	(0.136)	(0.014)	(0.116)
Medical sciences	0.330***	2.084***	0.155***	1.535***
	(0.043)	(0.231)	(0.022)	(0.210)
Social sciences	-0.016*	0.004	-0.010*	-0.056
	(0.009)	(0.107)	(0.005)	(0.081)
PhD grant	0.038**	0.337***	0.022**	0.352***
	(0.017)	(0.103)	(0.011)	(0.076)
Research project grant	0.061	0.290	0.025	0.311
	(0.041)	(0.213)	(0.022)	(0.192)
Constant	0.434***	3.793***	0.249***	2.685***
	(0.077)	(0.353)	(0.062)	(0.304)
Observations	2,488	2,488	2,488	2,488
R-squared	0.128	0.211	0.074	0.145

***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors are denoted in parentheses. Humanities is the reference group with respect to fields.

The results for the control variables show that age during the PhD is a predictor of both research productivity and visibility. The younger the PhD students are, the greater their research productivity and visibility during the degree. Completing a PhD in Portugal exerts a positive effect on visibility and the visibility of the publications co-authored with peers based abroad. Completing a PhD at the oldest Portuguese universities has a significant effect on research productivity during the PhD, but a negative effect on productivity conducted with peers based abroad (an expected result due to the critical mass that these universities possess; Horta and Lacy, 2011). The greater the time elapsed between the previous degree and the PhD the higher are both productivity and visibility, except for the research productivity of publications co-authored with peers based abroad. Changing fields between the previous degree and the PhD solely leads to publishing more with researchers based abroad.

Table 7 shows the effect of PhD funding sources on career research performance (i.e. after the PhD is concluded). In estimating the marginal effects of *PhD grant* and *research project grant*, the regressions control for the research performance variables achieved during the PhD. Indeed, research productivity is a well-known determinant of career research productivity (see Dietz and Bozeman, 2005; Horta and Santos, 2014). Our findings confirm that these variables are important predictors of career research performance. For every article published during the PhD, 0.983 more articles per year were published during the career, holding all other variables constant. These results are consistent with the findings in Dietz and Bozeman (2005), who surveyed the CVs of 1,200 US researchers and demonstrated that precocity, measured as the number of publications appearing during or before the year the doctorate was awarded, is positively and significantly associated with career productivity. They are also consistent with Horta and Santos (2014), who found that those who published during the PhD had 37% more career publications than did those who did not. Our results also show that articles published with peers based abroad during the PhD (Model 3) as well as their visibility (Model 4) are predictors of research performance throughout the researchers' career.

Our findings show that the *PhD grant* significantly increases research productivity at a 1% significance level (Model 1). Those benefiting from a *PhD grant* publish 23% more articles per year during their career than do those who are not. The effects of the

PhD grant on career research performance are not limited to the number of publications that researchers publish during their career because those benefiting from *PhD grants* receive 13% more yearly citations per article throughout their careers. This result also holds for publications co-authored with peers based abroad (with 19% more yearly citations per article). No statistically significant differences concerning career research performance were found between those supported by *research project grants* and those funded by their own funds during the PhD. The exception is that *research project grants* have a negative significant effect on research productivity with peers based abroad (at a 5% significance level). This analysis suggests that the impact of *research project grants* is limited (even detrimental) and that *PhD grants* can be considered the PhD funding source best able to foster research performance during and after the PhD.

Table 7. PhD funding as a determinant of career research performance

OLS regression	*Career productivity*	*Career visibility*	*Career Productivity with peers abroad*	*Career Visibility of publications with peers abroad*
	(1)	(2)	(3)	(4)
PhD productivity	0.983***			
	(0.102)			
PhD visibility		0.676***		
		(0.025)		
Productivity with peers abroad during PhD			0.499***	
			(0.052)	
Visibility of publications with peers abroad during PhD				0.477***
				(0.064)
Nationality (Portuguese =1)	0.133*	-0.260	-0.003	-0.078
	(0.075)	(0.176)	(0.044)	(0.223)
Age at PhD	-0.013***	-0.056***	-0.002*	-0.050***
	(0.003)	(0.008)	(0.001)	(0.008)
Gender (Male =1)	0.081*	-0.115	0.028	0.050
	(0.043)	(0.091)	(0.020)	(0.110)
Field change to the PhD	-0.011	-0.002	-0.003	0.093
	(0.053)	(0.111)	(0.014)	(0.142)
Graduated in a prestigious university	-0.100**	0.027	-0.035*	0.095
	(0.039)	(0.105)	(0.016)	(0.136)
Time to PhD	-0.008*	0.018*	-0.003**	0.020*
	(0.004)	(0.010)	(0.001)	(0.011)
More degrees before the PhD	-0.093**	-0.071	-0.035**	-0.234**
	(0.043)	(0.106)	(0.012)	(0.114)
Agriculture	0.281***	1.309***	0.088***	1.039***
	(0.071)	(0.221)	(0.006)	(0.247)
Engineering and technology	0.119**	0.960***	0.040***	0.569***
	(0.051)	(0.146)	(0.009)	(0.174)
Natural sciences	0.216***	1.100***	0.119***	0.989***
	(0.055)	(0.155)	(0.010)	(0.170)
Medical sciences	0.202**	1.032***	0.069***	1.155***
	(0.086)	(0.186)	(0.014)	(0.234)

Social sciences	0.053	0.455***	0.019***	0.228*
	(0.035)	(0.148)	(0.002)	(0.127)
Years after the PhD	-0.015***	-0.086***	-0.001	-0.070***
	(0.003)	(0.007)	(0.001)	(0.008)
PhD inside Portugal	0.103*	-0.137	0.027	0.083
	(0.059)	(0.144)	(0.027)	(0.157)
PhD in oldest Portuguese universities	0.006	0.223*	-0.021	0.002
	(0.057)	(0.129)	(0.037)	(0.148)
Number of international moves	0.040	0.050	0.035**	0.163**
	(0.025)	(0.055)	(0.012)	(0.070)
Number of job changes	-0.023	-0.001	-0.005	0.097
	(0.019)	(0.056)	(0.007)	(0.075)
Publications in different fields	1.076***	0.797***	0.347***	1.177***
	(0.069)	(0.102)	(0.031)	(0.160)
Working in the academia	0.158***	0.414***	0.007	0.282**
	(0.054)	(0.116)	(0.015)	(0.133)
International network	0.001	0.057		
	(0.010)	(0.058)		
PhD grant	0.113***	0.197**	0.000	0.203**
	(0.041)	(0.096)	(0.008)	(0.097)
Research project grant	0.019	0.266	-0.041**	0.417
	(0.089)	(0.188)	(0.014)	(0.283)
Constant	0.318**	2.996***	0.091	2.200***
	(0.142)	(0.405)	(0.082)	(0.425)
Observations	2,441	2,441	2,441	2,441
R-squared	0.417	0.581	0.304	0.342

***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors are denoted in parentheses. Humanities is the reference group with respect to fields. Total observations decreases of 47 (from 2,488 to 2,441) due to lack of data for the variables "Number of job changes".

For the control variables, age during PhD is found to be negatively associated with career research productivity and visibility: those who are younger exhibit greater research productivity and have greater visibility, as is expected in a scientific system whose younger generation of PhDs is much more engaged in publishing, particularly publishing among the international research community (Heitor et al., 2014). This is corroborated by the fact that those who have shorter careers have better research performances, except for career publications with peers based abroad. Gender does not seem to be a major predictor of research performance, except for research productivity—where males out-produce females. The analysis of mobility shows that research field mobility is a significant predictor of career research productivity and visibility, while international mobility positively affects research productivity and visibility with peers based abroad. Unlike the two previous mobility types, job mobility evinces no statistically significant relationship with any of the research performance variables.

5. Conclusion

Our analysis shows that being awarded a doctoral grant has positive effects on research performance during the PhD and throughout the career. This result is consistent with previous findings that the availability of and access to public funding can influence early-career researchers' performance (Arora and Gambardella, 2010). Our findings also show that different PhD funding schemes vary in their effects on research performance during and after the PhD. *PhD grants* enhance research productivity and visibility during the doctorate and throughout the research career. Research performance during the PhD does not differ between those who benefited from *research project grants* and those who did not. *Research project grants* even affect negatively the career research productivity with peers based abroad, making this doctoral funding scheme to be arguably even detrimental to researchers' career research performance. Furthermore, only those awarded *PhD grants* were able to enjoy enhanced research performance from co-authorship with colleagues based abroad during the PhD and also during their career. Thus, *research grant projects* fall short of *PhD grants*' impact on both the PhD and the career.

These results demonstrate that public funding for science, particularly through *PhD competitive grants*—which provide stability so that doctoral research may be undertaken with a clear focus on the PhD research objectives—allows PhDs to make a greater contribution to the scientific development of their fields, institutions, and scientific systems. This effect occurs both during and after the PhD and also extends to the publication of articles with peers based abroad. That these effects do not apply to PhD students supported by *research project grants* can be explained in several ways. First, the pressure and workload of research projects may present problems. In addition, PhD students may be encumbered by intensive administrative tasks related to the projects, consuming the research time essential for producing higher-quality research.

The undistinguished research performance impact during the PhD seen in those awarded *research project grants* and in those without may also be related to the fact that work published during research projects may not be directly related to the core theme of the PhD, which can be aggravated by the funding uncertainty experienced by PhD students awarded *research project grants*. Forced engagement in multiple *research project grants* during the PhD can also cause problems, as when a PhD student's project ends, forcing the student to find another project through which to maintain funding; this

may force students to adopt a multitude of research foci that prevent them from establishing a more coherent research agenda for their PhD research objectives. Unfortunately, the data available do not allow us to explore these issues at this time. A further caveat associated to data constrains, refers to the impossibility to have data on the PhD mentors, which would allow for a better understanding of the mentor's role between PhD funding and research performance. These issues require new data and must be explored in future research because, in a socialization stage as important as the PhD, the role of the mentor and the potentially disruptive dynamics of research projects may clearly detract from students' research productivity and visibility during their PhD and throughout their careers.

Our results highlight the importance of offering grant schemes that will guarantee the stability PhD students need to focus on their doctoral research. Such schemes will also guarantee the awardees a much stronger autonomy and focus. One conclusive result of this study is that the contribution to science made by those funded by *grants* is always more significant than is that made by their unfunded peers, highlighting the critical role of the competitive public funding of PhD students in developing scientific systems.

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CHAPTER 5. Concluding remarks

The findings of this thesis make several contributions to the literature on higher education. Oeverall, important implications and research avenues have been identified across the different topics investigated in this research project.

The first paper highlights that in addition to their primary scope of competing in the international context for students, faculty and research funds, the international characterization of university plays a significant role in certifying the entrepreneurial activity of affiliated firms. Although our results might be not surprising, this paper is one of the few contributions in the literature investigating the externalies of university internationalization towards the industry. In particular, we are the first assessing that the affiliation with a university positively influences the attractiveness of firms in the eyes of foreign acquirers. In particular, the more internationalized, and prestigious, is the university, the more is the interest from international partners. The latter clearly appreciate the potential of such affiliated firms, preferring them in cross-border M&A activity. This evidence underlines that the internationalization of universities might increase the value of university-industry relationship. Acting as intermediaries of internationalization, internationalized universities may create symbiotic relationships with firms, which in turn might certify their quality in the (international) market for assets. These results suggest that future research should in-depth investigate the externalities of university internationalization on the local environment, both considering the benefits for single firms and the advantages in terms of regions' development and competitiveness. Further, it might be interesting to disentagle which type of university internationalization matter the most to foster firms and regions growth. It is indeed acknowledged that university internationalization takes different forms (e.g., % of international professors, % of international students, % of international publications, etc...)

The second paper studies the competition arisen among universities to attract students, considering both the spatial and the temporal dimension. After controlling for well-known characteristics affecting universities' attractiveness to students, results suggest that Italian universities have been subject to enrolment competition over the last decade, thereby influencing their attractiveness to students. Further, by evaluating such competition over time, we document that the recent financial crisis led students and families to be more selective when choosing a university. As a matter of fact, universities

in close proximity to others (i.e., belonging to agglomerated "clusters"), and therefore those more likely to have faced a higher level of competition, have become more attractive to students. These results have important implications for understandings of the migration of highly skilled human capital and its associated positive externalities. As more competitive university clusters could attract more students towards specific areas, this might affect the growth and the competitiveness of specific regions over time. Based on the assumption that the amount of highly-skilled human capital is a strong predictor of regional economic development, future research might consequently wonder whether the competition developed among universities for attractiveness to students may affect local development. A higher degree of competition for students is indeed known to improves universities' teaching performance and, in the case of international students, technical efficiency. In addition, competition has been also recognized to increase the diversity of disciplines offered of universities and also the modalities of course delivery, thus increasing the knowledge and the skills of graduates.

Finally, the last work focuses on the impact that different forms of funding at a PhD level might affect the research performance of newly academics across their career. Results highlight that being awarded a doctoral grant has positive effects on research performance during the PhD and throughout the career. However, different PhD funding schemes vary in their effects on research performance during and after the PhD. We also find that PhD funding schemes that privilege long-term PhD funding stability (i.e. PhD grants) positively affect research performance during the PhD and throughout the career, while those awarded research project grants during their PhD do not benefit from this effect. Specifically, we argue that the latter funding scheme has more limited effects because of the constraints typical of early-stage researchers involved in research project dynamics. Because of data limitations, we were not able to control for the role of the PhD supervisor in affecting the research performance of his/her PhD students. Future research should investigate whether the characteristics of supervisors (e.g., academic rank, field of research) and the different modalities of student-supervisor interaction moderate the impact of doctoral funding sources on the research performance during and after the PhD program. Further, following the literature documenting the effect of research grants on the researcher productivity of scholars, future contribution should replace our analysis comparing PhD students' research performance in different higher education systems.