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Stimulating graduates' research-oriented careers: does academic research matter?

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Stimulating graduates' research-oriented careers: does academic research matter? *

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Abstract

This paper investigates whether the quality of higher education and, in particular, its research performance stimulate graduates' research-oriented careers. More specifically, exploiting a very rich data-set on university graduates and the higher education institutions they attended, we empirically study whether graduates from universities and programs that display better academic research records are more likely to be enroled in PhDs or employed as researchers three years after graduation. Controlling for a number of individual and university covariates and using different proxies for research performance, we find that the likelihood of entering a research-oriented career increases with the quality of academic research. Notably, the inclusion of university fixed-effects shows that this result does not stem from unobserved university heterogeneity. Our finding is stronger for graduates in science, medicine, and engineering.

JEL Classification: I23, O30, O38.
Keywords: Academic research, labor market for scientist, post-graduate education.

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1 Introduction

In the last years, especially in Europe, heads of governments and international institutions have continued to stress the need to boost substantially the number of people entering science and technology careers. Policy makers and alike have often emphasized the importance of the number of researchers as a share of the employed population as both an indicator and a target for science and technology policy.[1] For instance, the last European Commission green paper states that the so-called European Research Area should comprise among top priorities "an adequate flow of competent researchers" (European Commision, 2007). As noticed by Freeman and Goroff (2008), similar concerns over the science and engineering job market have been expressed on the other side of the Atlantic. In his 2006 state of the Union address, President Bush stressed that "for the U.S. to maintain its global economic leadership, we must ensure a continuous supply of highly trained mathematicians, scientists, engineers, technicians, and scientific support staff".

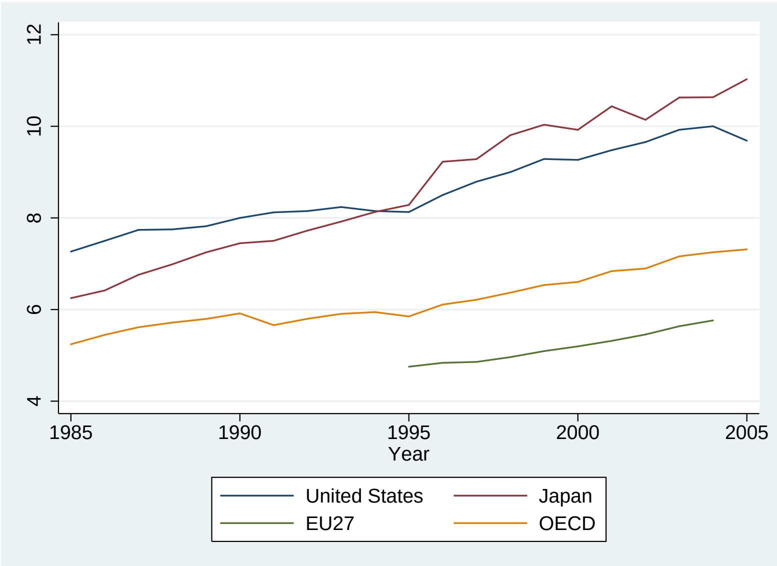
According to most science and technology indicators, despite the intention expressed in the Lisbon declaration of becoming the most dynamic and competitive knowledge-based economy in the world, Europe is not closing the gap with other industrialized countries (see, for example, van Pottelsberghe (2008) and Dosi at al. (2006)). In particular, as shown in Figure 1, in the last decade the number of researchers per thousand employment has been consistently lower than in the US and Japan. However, a first look at data on higher education attainment shows that, despite a lower aggregate graduation rate, EU countries produce more graduates in science and engineering disciplines than the US and Japan. According to OECD (2008), in 2006 the science graduates per 100 25-to-34-year-olds in employment were 1.62 in the EU, 1.37 in the US, and 1.61 in Japan (see Table 1).[2] The European Commission green paper mentioned above singles out the labor market for researchers as the possible culprit for the low number of graduates entering a research-oriented career and it speculates that in Europe the imbalances within national labor markets lead many graduates potentially suitable to become researchers to find better employment and career prospects either in other economic sectors or on the other side of the the Atlantic (European Commision, 2007).

Together with a well functioning labor market, however, a relevant factor to stimulate an adequate flow of competent researchers is the quality of higher education systems. In the last years, the increasing internationalization of tertiary education came together with increasing scrutiny of the differences in the performance of countries' universities. The quality of higher education institutions is

[1]Differently from more traditional input indicators like investments in R&D, the number of researches in the employed population do not reflect differences in prices and wages.

[2]Science fields include life sciences; physical sciences, mathematics and statistics; computing; engineering and engineering trades, manufacturing and processing, architecture and building.

Figure 1: Researchers per thousand employment



Note: Researchers are defined as professionals engaged in the conception and creation of new knowledge, products, processes, methods and systems. They are directly involved in the management of projects and are expressed in full-time equivalent.
Source: OECD, Main Science Technology Industry database.

thought to be especially important for advancing science, technology, and those industries that depend upon them. More specifically, the literature has traditionally focused on two channels. First, through their teaching and training activities, universities disseminate knowledge and improve the stock and the quality of human capital of a country. As recently documented by Moretti (2004), college education has also substantial spillovers on less educated labor force, as revealed by the positive relationship between individual wages and the share of college graduates, even after controlling for the direct effect of individual education on wages. Second, through academic research, higher education institutions push forward the knowledge frontier and often transfer its benefits to the rest of society. In the aggregate, moreover, teaching and research are believed to be complements and to reinforce each other. In a paper closely related with the present one, we find that academic excellence is positively correlated with the employment performance of college graduates, suggesting that the quality of research and teaching activity are indeed intertwined across institutions and programs (Sylos Labini and Zinovyeva, 2009). The present article explores whether the quality of higher education and, in particular, its research performance stimulate graduates' research-oriented careers.

The excellence of academic research is likely to be important for at least two reasons. First, as far as the supply side is concerned, being exposed to faculties with better research records may increase graduates' abilities and willingness to pursue a research-oriented career. Second, on the demand side, one expects that universities, research institutions and corporate actors are more eager to hire young researchers if their skills and abilities are higher.

International comparisons suggest that indeed proficiency in science disciplines and the academic excellence are likely to boost research-oriented jobs. As shown in Figures 2 and 3, the number of researchers is higher in countries where (i) high school students are more proficient in science, as revealed by the OECD Programme for International Student Assessment (OECD-PISA) data, and (ii) higher education institutions display better results in the Shanghai academic ranking of world universities.

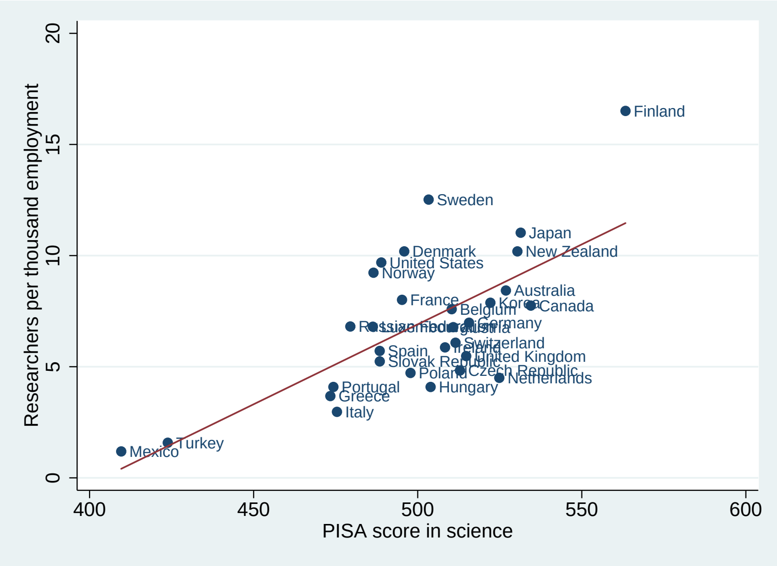
It is of course problematic to interpret the displayed correlations as causal, because of the high cross-country heterogeneity and the many relevant omitted variables. For example, among others difficult-to-observe determinants of the likelihood of undertaking research-oriented careers, labor market institutions and public and private demand for researchers are likely to be correlated with the quality of education systems. Therefore, exploiting within country variation in academic research quality seems to be a more promising strategy to address the main question of our study. This paper concentrates on Italy, which is a suitable candidate both for data availability and the high variation of university quality within its borders.

More specifically, exploiting a very rich data-set on university graduates and the higher education institutions they attended, we empirically study whether graduates from institutions and programs that display better academic research records are more likely to be enroled in doctoral programs or to be employed as researchers three years after graduation.

Controlling for a number of individual and university covariates, we find that the quality of academic research is positively correlated with the likelihood of undertaking a research-oriented career. This finding is robust to two important checks. First, it still holds after controlling for geographical and university fixed-effects. This rules out the possibility that it stems from unobserved university characteristics. Second, we obtain the same result if we consider only those individuals who graduated from departments that did not offer doctoral training. This suggests that the correlation between academic excellence and the pursuit research-oriented career is not due entirely to the capability of good faculties to attract funds for doctoral programs. It is also important to stress that, as the common wisdom suggests, our finding is stronger for graduates in science, medicine, and engineering.

The rest of the paper is organized as follows. Section 2 provides some information on the Italian system of higher education and research and locates our contribution in the relevant literature. Section 3 presents a description of the data.

Figure 2: Researchers per thousand employment and OECD-PISA scores in science



Note: Researchers per thousand employment is measured in 2005 for all counties but Turkey, Italy, France, and Australia (2004); Netherlands, New Zealand (2003); and United Kingdom (1998). OECD-PISA scores in science refer to 2006.
Source: OECD, Main Science and Technology Indicators database and OECD-PISA.

Section 4 discusses our empirical strategy and shows our main results. Section 5 concludes.

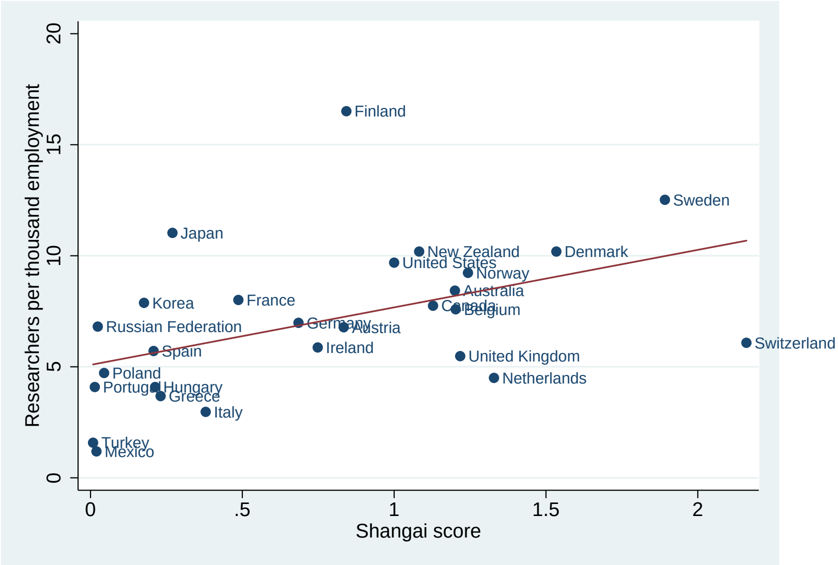
2 Background

2.1 The Italian system of higher education and research

Higher education data shows that Italy performs poorly compared to other industrialized countries. In 2006 the share of Italian population aged 25-34 with tertiary education was only 17 per cent, compared to an OECD average of 33 (OECD, 2008). As shown in the first column of Table 1, although the gap is somewhat smaller, Italy lags behind also in the production of graduates in science. Unfortunately, international indicators on graduates' skills and proficiency are lacking and, thus, cross-country comparisons of the quality of Italian graduates are not straightforward. However, long non-employment spells and relatively low wages suggest that Italian graduates are not the 'happy few'.

As far as the quality of academic research is concerned, recently published international rankings indicate that the performance gap between Italian and other developed country universities is large and increasing. For example, according to

Figure 3: Researchers per thousand employment and the Shanghai ranking



Note: Researchers per thousand employment is measured in 2005 for all countries but Turkey, Italy, France, and Australia (2004); Netherlands, New Zealand (2003); and United Kingdom (1998). Shanghai scores are calculated for each country using the 2008 Shanghai ranking of top 500 world universities following the methodology described in Aghion at al. (2007).
Source: OECD, Main Science and Technology Indicators database and our calculation on the Shanghai ranking data (available at `http://www.arwu.org`).

the 2008 Shanghai ranking,[3] no Italian university is among the world top 100, only 22 are in the top 500, and most of them have lost ground in the last six years.[4] Nevertheless, the first evaluation exercise sponsored by the Italian Ministry of education has shown that there is a remarkable cross-university and cross-field variation in the excellence of academic research (see Section 3.2 for details).

Table 1 shows that the number of researchers in Italy is low compared to other industrialized countries. Moreover, a high share of Italian PhD recipients graduated in the US and this reveals the weaknesses of Italian post-graduate education.

2.2 Literature

This work is mostly related with two streams of literature. The first concerns the effect of higher education on economic performance. Recent research has pointed out that when a country moves closer to the international technological frontier, tertiary education becomes increasingly important (Aghion at al., 2005;

[3]Compared to other international rankings, the Shanghai one measures mostly research (vs. teaching) quality and relies on publicly available indicators. Information on the basic features of the Shanghai ranking and its methodology is available at `http://www.arwu.org/`.

[4]The year of the Shanghai ranking first edition is 2003.

Table 1: Italy in comparative perspective

	Science graduates	Graduation rates in PhD	Researchers	PhDs delivered in the US
Australia	2.62	1.79	8.43	1.49
France	2.71	1.23	8.01	1.34
Germany	1.42	2.32	7.00	1.77
Italy	**1.42**	**1.20**	**2.97**	**5.30**
Japan	1.61	0.97	11.03	2.65
Korea	3.86	1.04	7.88	26.54
Spain	1.29	1.01	5.71	2.20
United Kingdom	2.29	2.17	5.48	1.24
United States	1.37	1.41	9.69	.
OECD average	**1.69**	**1.39**	**7.31**	.
EU average	**1.62**	**1.55**	**5.76**	**2,59**

Notes: Science graduates is the number of science graduates per 100 25-to-34-year-olds in employment. Graduation rates in PhD is expressed as percentage of PhD graduates to the population at the typical age of graduation. Researchers is the number of researchers per 1 000 total employment and is measured in 2005. Science graduates, graduation rates in PhD are measured in 2006. PhDs delivered in the US is expressed in percentages and are relative to the total PhD delivered nationally. It is measured in 2004.
Sources: OECD (2008) and OECD Science, Technology and Industry Scoreboard.

Vandenbussche et al., 2006). Investments in tertiary education are likely to foster complementary investments in research and development and this might further stimulate technological innovation and economic growth. However, beyond aggregate investments, also the quality of higher education seems to be important. In a recent article, Abramovsky et al. (2007) investigate the relationship between the quality of academic research in Great Britain and the location of private sector R&D labs. They find that, especially in pharmaceuticals, corporate actors are disproportionately located near to those research universities that are evaluated as excellent by the British research assessment. This paper concentrates on an additional channel through which the quality of higher education may enhance economic growth: the impact of academic research excellence on the number of graduates undertaking a research-oriented career.

The second stream of literature is more policy-oriented: a few studies have recently pointed out the practical difficulty with government efforts to increase inventive activity and tried to evaluate the effect of distinct policies on the labor market for scientist and engineers (Goolsbee, 1998; Romer, 2000; Freeman and Goroff, 2008). One of the insights of this literature is that researchers labor supply is quite inelastic, so when the government subsidies R&D, a significant fraction of the increased spending translates directly into higher wages. Conversely, if the objective is to increase the number of researchers on the labor force, factors believed to be important are a strong research base, sound financial institutions, a rigorous education system, robust regulation, good infrastructure, and an attractive environment for internationally mobile scientists. In this paper, we concentrate on importance of policies aimed at strengthening the quality of academic research.

3 The data

3.1 Graduates characteristics and research-oriented careers

The empirical analysis of this study exploits data drawn from several sources. First, information on university graduates comes from two almost identical surveys on the university-to-work transition in Italy (*Indagine Inserimento Professionale Laureati*) run by the the Italian National Institute of Statistics (ISTAT) in 1998 and 2001 on representative samples of individuals who graduated from Italian universities in 1995 and 1998 respectively. In both years the sample is stratified according to sex, university and university degree and in the analysis below all estimations are performed using stratification weights. The surveys provide information on (i) individual socio-economic background and those characteristics predetermined with respect to college choice and outcomes, (ii) college-related individual indicators and (iii) labor market outcomes. For each respondent, we have information on gender, age, high school grade, actual region of residence, province of residence before attending tertiary education, attended university, degree of study, final grade, parents' education, and parents' occupation. A complete description of the variables is provided in the Appendix.

Key for our purposes are two questions related to actual educational and occupational status. First, individuals are asked whether they are currently enroled in a PhD program; second, if employed they are asked about the type of their occupation they and being a researcher is one of the alternatives. Moreover, we also know whether they are employed in the private or the public sector. As shown in Table 2, about 6.4 per cent of graduates are in a research-oriented career. About three fourths of them are in a doctoral programs and this roughly corresponds to aggregate official figures provided by the ministry of education. The share of PhD students and researchers grows to almost 11 per cent for graduates in science, medicine and engineering.

3.2 Measures of research quality

Survey data on graduates are combined with information on the universe of Italian universities and departments. In particular, we use three different sources of indicators to measure the quality of research output. The first provides indicators related to all scientific areas; on the contrary, the second and the third are only available for science, medicine and engineering.

The most comprehensive and reliable measure is drawn from a national-wide evaluation of the academic research output produced by all Italian universities from 2001 to 2003. The evaluation was performed by the Committee for Evaluation of Research (CIVR), appointed by the Italian ministry of Education and its results were published at the beginning of 2006.[5] It was the first research assessment exercise done in Italy and it consisted of three steps. First, each university had to present a number of its best "scientific products" published during 2001-2003.[6] The number varied with the full time equivalent researchers enroled in each institution and, overall, 17,329 products were evaluated. Second, 20 panels, 14 for single scientific areas and 6 for interdisciplinary scientific areas, graded the received scientific products. Each panel was composed by 5-17 members, who were helped by 6,661 field experts (each product was evaluated by at least 2 experts), who were supposed to rely on the quality, relevance, originality, and international impact of the product. Finally, each panel produced both a report and a ranking list. The 14 ranking lists of the single scientific discipline panels are used in this work as the main measure of research quality of universities and departments. To match scientific areas with graduates' attended programs, we create a table of conversion which is available from the authors upon request. Hereafter, scientific areas, departments, and programs are treated as equivalent unit of analysis.

The second set of measures on university research is drawn from the the Thompson ISI data-set on scientific journal publications. In particular, we use the number of publications and citations in the quinquennium 1995-1999. These variables were collected and organized at the level of university and scientific discipline by a group of researchers of the Conference of Italian University Presidents (*CRUI*) statistic office (Breno et al., 2002). This information is available for 9 scientific areas: Mathematics and Informatics, Physics, Earth Sciences, Biosciences, Pharmacy and Chemistry, Medicine and Surgery, Veterinary and Agriculture, Construction Engineering and Architecture, and Industrial Engineering. They are comparable with the 14 CIVR sectors, but five areas (humanities, history, economics and statistics, political science, and law) are not included.

The three measures collected are believed to be highly correlated and indeed, as we show below, they are. However, CIVR ranking and the number of citations per professor are thought to reflect output quality. Conversely, publications per professor reflect the average scientific productivity in a given department and thus it is less sensitive to the presence of a few outstanding researchers.

Finally, we also consider two indicators related to market-oriented academic research: the number of patents and patents' citations registered from 1993 to 1998

[5] All data and relevant documents are available on-line at `http://vtr2006.cineca.it`.

[6] The definition of a "scientific product" includes books, book chapters, articles, patents, projects, and artistic works.

at the European Patent Office.[7] We draw this information from the KEINS data set on academic patenting (Lissoni et al., 2006). Italian universities do not generally own the patents authored by their faculties and this makes difficult to attach patents to university researchers. However, the KEINS database matches by name and surname all EPO applications, reclassified by applicant and inventor, with a list of university professors. Thanks to this methodology, the KEINS database includes also those patents that originate from university scientists, but are owned by corporate actors, research organizations, or by the scientists themselves.

Table 3 reports the cross-correlations between the above measures of academic research quality. As mentioned, despite the different nature and sources of these variables, they are highly correlated.

3.3 University and department variables

We augment our university- and department-level data with a number of additional control variables drawn from several editions of the ISTAT bulletin *The state of Italian Universities in numbers* and from official web page of the Ministry of education (*http://statistica.miur.it*). At the department-level, we know the number of professors, their average age, the number of students enrolled, the number of graduates, and the number of PhD scholarships available. Note that in Italy the number of PhD students is not completely supply driven. For example, according to official data, in 2001-2002 academic year 47 percent of doctoral programs had at least one available position unfilled. At the same time, in 13 percent of programs, more people were accepted than initially planned. At the university-level, we also know whether a given institution is public or private.

Table 2 reports summary statistics for all the variables mentioned above.

4 Empirical results

As shown in Figure 4, the likelihood of being either enroled in a PhD program or employed as a researcher is higher for graduates from departments with better research scores, as revealed by the CIVR expert evaluation exercise. Note that the statistical association is higher for graduates in science, medicine, and engineering departments. Of course, several individual, department and university covariates are likely to be correlated with both the probability of being in a research-oriented career and the quality of academic research.

[7] More precisely, the database includes all patent applications that passed a preliminary examination in the EPO. The assigned date of the patent is the priority date, which is the date of the first filing world-wide.

Table 2: Summary statistics

	All disciplines				Science, Medicine and Engineering			
Variables	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max
Individual characteristics								
Age	27	4	21	71	27	3	22	71
Female	0.540		0	1	0.448		0	1
High-school grade	49	7	36	60	50	7	36	60
University grade	104	7	70	111	104	7	70	111
Researcher or PhD student	0.064		0	1	0.107		0	1
- Enrolled in a PhD program	0.049		0	1	0.078		0	1
- Work as a researcher	0.018		0	1	0.033		0	1
Employed	0.751		0	1	0.758		0	1
Used university or professor recommendations for getting a current job	0.034		0	1	0.046		0	1
Department characteristics								
Private university	0.064		0	1	0.012		0	1
Number of professors	160	126	3	1022	195	151	9	1022
Mean professor age	49	3	37	55	50	3	37	53
Student-professor ratio	28	25	1	229	12	6	1	46
Graduates	712	635	9	2492	512	604	9	2281
PhD scholarships per graduate	0.054	0.062	0	0.474	0.092	0.072	0	0.474
CIVR	0.783	0.098	0.370	1	0.798	0.069	0.500	1
Publications per professor	n/a				0.755	0.639	0	3
Citations per professor	n/a				2.821	3.333	0	16
Patents per professor	n/a				0.004	0.007	0	0.037
Patent citations per professor	n/a				0.006	0.012	0	0.094
Number of observations	37086				16346			

Notes: n/a means that information is not available. All variables are defined in the Appendix.

Table 3: Correlation among measures of research quality

		(1)	(2)	(3)	(4)	(5)
(1)	CIVR score	1				
(2)	Publications per professor	0.416***	1			
		(0.000)				
(3)	Citations per professor	0.440***	0.900***	1		
		(0.000)	(0.000)			
(4)	Patents per professor	0.181***	0.281***	0.219***	1	
		(0.002)	(0.000)	(0.000)		
(5)	Patent citations per professor	0.139**	0.201***	0.177***	0.830***	1
		(0.019)	(0.001)	(0.003)	(0.000)	

Notes: the table shows correlation among the research quality indicators at the department level. Publications, patents, and citations are per professor. The number in parenthesis is the significance level of each correlation coefficient.

For instance, individuals with better school performance might enroll in universities and departments with better research records and this would make the above correlation spurious. Similarly, graduates from institutions and programs with a higher number of PhD scholarships, or located in areas where labor demand for researchers is higher, are more likely to undertake research-oriented careers for reasons different from the excellence of the academic research carried on by their instructors.

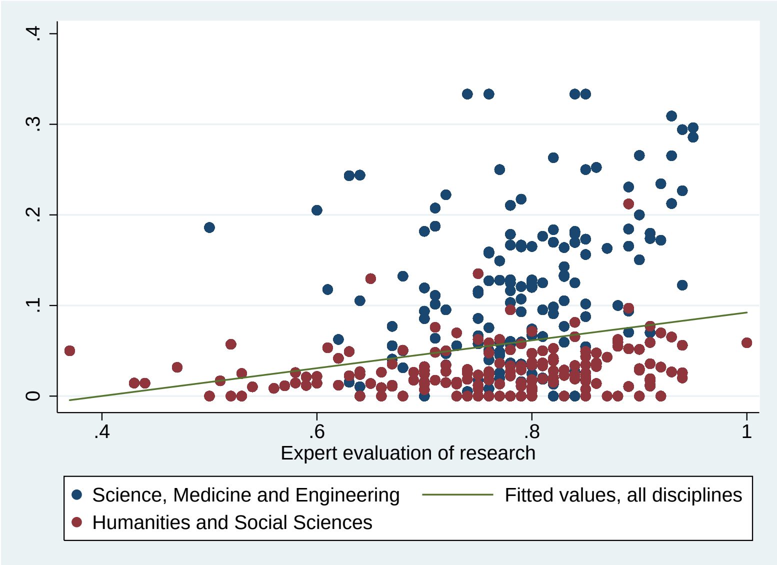
4.1 Individual and university controls

To check whether the correlation depicted in Figure 4 is robust to a number of controls, we estimate the following regression:

$$Research\ career_{idu} = \alpha + \beta X_{idu} + \delta E_{du} + \eta Research\ quality_{du} + \varepsilon_{idu} \quad , \qquad (1)$$

where *Research career* is a binary variable that assumes value 1 if the individual i graduated from department d and university u is either enroled in a PhD or employed as a researcher and 0 otherwise. X is a set of individual controls including gender, age, high school grade and type, province of residence before entering tertiary education, parents education. E is a vector including university and department level controls. *Research quality* is an indicator of research performance and is measured at the department d level. As usual, ε is the unobserved residual. Our main objectives are to obtain a reliable estimate of η and to rule out the most serious concerns to interpret it as the *ceteris paribus* effect of research quality on the probability of becoming a researcher.

Figure 4: Research oriented careers and CIVR scores



Note: The vertical axis displays the share of graduates in a research-oriented career. Each point represents the average within a given department. University-scientific discipline areas with less than 15 graduates surveyed are excluded.

Table 4 reports the linear probability model estimates (LPM) of the above parameter, while in the Appendix are depicted the coefficients of all controls. Probit estimates display very similar results, both in terms of magnitudes and statistical significance, and are available from the authors upon request. Here, the LPM is preferred for two basic reasons: first, differently from non-linear binary response models, it yields unbiased and consistent estimates with no assumptions on the error shape. Second, the LPM allows to estimate dummy coefficients for membership in some group also when every member of the group has the same value for the dependent variable. The two main drawbacks of LPM with respect to probit and logit — i.e. predicted probabilities outside the 0-1 interval and heteroskedasticity — are not particularly severe for our scopes: first, our main objective is not predictive in nature. Second, all standard errors reported are corrected for the potential clustering of the residual at the university-times-scientific area level and are heteroskedasticity-robust.

In the specification displayed in the first row of Table 4, we only include individual controls and dummies for degree of study. Column 1 reports the results obtained using the entire sample of graduates (i.e. including humanities and social sciences degrees). The positive correlation between the CIVR score and the likelihood of entering a research-oriented career observed in Figure 4 still holds: the coefficient is positive and statistically significant at the 5 per cent level. A causal interpretation implies that the reported coefficients are the effect of a marginal change of the CIVR score on the probability of undertaking a research-oriented career. Thus, according to our estimates, a one-standard-deviation increase in the CIVR score increases the probability of undertaking a research career by about 0.4 percentage points. According to the results reported in the Appendix, females and graduates with lower high school performance have a lower probability to be in a research-oriented career. On the contrary, the same probability is higher for graduates with at least one parent who attained tertiary education.

Column 2 of Table 4 shows that the effect of research quality is higher for graduates in science, medicine, and engineering: a one-standard-deviation increase in the CIVR score augments the likelihood of becoming a researcher by more than 0.8 percentage points.[8] This is not a negligible effect, taking into account that the outcome variable sample mean is about 10 per cent.

As mentioned at the beginning of this Section, even assuming that we controlled for the whole set of the relevant individual characteristics, the above findings might still be driven by omitted variables at the university- or department-level. Thus, we add to our baseline regression a number of additional controls related with university and department characteristics: the number of professor, the student professor ratio, the number of graduates, a dummy which assumes value 1 if a given institution is private, and, more importantly, dummies for the region where the university is located. Note that, including these dummies, we exploit only the variation in research performances within regions. Although these controls are potentially endogenous, they capture difficult-to-observe labor market characteristics. As shown in the second line of Table 4, our previous finding is largely confirmed, although the coefficient for science, medicine and engineering graduates is now significant only at the 10 per cent level.

In column 3 and 4, we explore whether our findings are consistent when we use our additional indicators of research quality. Results are remarkably similar: the correlations between the number of publications and citations per professor and the probability of undertaking a research career are positive and statistically significant either at the 1 or at the 5 per cent level. If we interpret these results as causal, we can say that one more publication per faculty increases the likelihood that a graduate from a given department enters a research oriented career by almost four percentage points. According to the displayed coefficients and the corresponding standard deviations, if we compare these results with the CIVR scores ones, the effects are higher for publications per professor and very similar for citations per professor: in the specification in which we control for university and department characteristics (second line), a one-standard-deviation increase in

[8]Note that the standard deviation of the CIVR score is smaller in science, medicine, and engineering departments.

the number of publications per professor and the number of citations per professor increase the likelihood of becoming a researcher by about 1.6 and 1.3 percentage points respectively. Again, if we interpret these coefficients as causal effects, the magnitudes are important.

Finally, we explore whether patents and patents' citations — our set of measures that capture market-oriented scientific productivity — also matter. Coefficients reported in column 5 and 6 reveal that both patent-related measures are positively associated with the probability of undertaking a research career. However, the OLS coefficients are statistically different from zero only for patents per professor when we control for university and department characteristics (second line column 5). This result might stem either from the lower variation of the patent-related variables (note that in many scientific disciplines patenting is not a normal activity), or from the distinct kinds of research skills and activities that patent production requires.

4.2 Supply of PhD positions and scholarships

As already mentioned, our definition of research-oriented careers includes being enroled in a PhD. In Italy most doctoral programs are endowed with publicly funded scholarships assigned at the university level. For example, according to official data, in 2001 about 60 per cent of all doctoral students were recipients of one of these scholarships. Given the low mobility of Italian graduate students (i.e. they often enrol in a PhD offered by the same university where they graduated), our findings are potentially driven by the number of PhD scholarships. The latter is in fact likely to be correlated with both the research performance of a given institution and the likelihood that internal graduates enrol in a doctoral program. To check for this possibility, we perform two additional checks. First, although also this control is potentially endogenous, we include among regressors the number of PhD scholarships granted at the department level. The coefficient of the new control is indeed positive and statistically different from zero,[9] however, as displayed in the third line of Table 4, our basic result on the effect of research quality still holds.

Second, we try to solve the problem relying only on those individuals who graduated from programs for which their institution did not offer a PhD. In their case, the number of funded scholarship cannot affect the likelihood of entering a research career. Although the number of observations is much smaller, as shown in the first column of Table 5 our basic finding still holds and is broadly consistent with previous results.

[9] This result is not reported but available upon request.

Table 4: Research-oriented careers and academic research quality

		1	2	3	4	5	6
	Specification	All disciplines	Sciences, Medicine and Engineering				
		CIVR score	CIVR score	Publications per professor	Citations per professor	Patents per professor	Patent citations per professor
I	Year, Degree, Individual characteristics	0.041**	0.120**	0.030***	0.004***	0.869	0.426
		(0.016)	(0.051)	(0.009)	(0.001)	(0.541)	(0.299)
II	I + University-discipline characteristics	0.042**	0.106*	0.026***	0.004**	1.347***	0.430
		(0.017)	(0.057)	(0.009)	(0.001)	(0.500)	(0.310)
III	II + PhD scholarships per graduate	0.044***	0.106*	0.026***	0.004**	1.346***	0.429
		(0.017)	(0.058)	(0.009)	(0.001)	(0.501)	(0.311)
IV	III + University fixed effects	0.030*	0.113*	0.039***	0.004**	1.217**	0.296
		(0.018)	(0.060)	(0.013)	(0.002)	(0.552)	(0.356)

Notes: OLS estimates. In parentheses - standard errors clustered for graduates from each university department. Number of observations in column 1 is 37086, in columns 2-5 – 16346.
* p-value<0.100, ** p-value<0.050, *** p-value<0.010.
Individual characteristics include gender, age groups, high-school grade, type of the high-school attended, province of residence before university, parents' education. University-discipline characteristics include (log) number of professors, student-professor ratio, (log) number of graduates, ownership control, region of university location.

Table 5: Research-oriented careers in departments with no PhD program

	1	2	3
	Research career	PhD	Researcher
CIVR score	0.071**	0.049*	0.035
	(0.033)	(0.026)	(0.024)
N	3159	3159	3159

Notes: OLS estimates on the sample of 1995 and 1998 graduates from the departments with no PhD programs. In parentheses - standard errors clustered for graduates from each university department. * p-value<0.100, ** p-value<0.050, *** p-value<0.010. All estimations include individual characteristics (gender, age, high-school grade, type of the high-school attended, region of residence before university, parents' education), university-discipline characteristics ((log) number of professors, student-professor ratio, (log) number of graduates, ownership control, region of university location), year and degree dummies.

4.3 University fixed-effects

In the analysis above, we indeed control for many different covariates. However, the doubt remains whether our result is driven by the true effect of the quality research or, conversely, by difficult-to-observe university characteristics. In fact, institutions with a better research performance are likely to differ from the others in several respects. Exploiting the basic fact that our measures of research quality are department specific, we include in our regression university fixed-effects. Thus, we identify the effect of research quality relying on cross-scientific areas heterogeneity in the quality of research. In other words, instead of comparing graduates from different universities, we check whether within the same institution graduates from those programs that perform relatively better are also more likely to be in a research career. The coefficients displayed in the fifth row of Table 4 are again very similar to the ones relative to the previous specifications and confirm our basic finding.

4.4 PhDs vs researchers

In this Section, we investigate whether the positive correlation holds for distinct types of research-oriented careers. In particular, we estimate the probability of being in a doctoral program and the probability of being employed as a researcher in two separate regressions.[10] In the former regression, we also use data from the 2004 ISTAT survey that — similarly to the 1998 and 2001 editions — contains information on whether graduates are enrolled in doctoral programs. Unfortunately,

[10]We also run a multinomial logit having as possible outcomes being a PhD student, being employed as a researcher, and everything else. Results are very similar to the ones presented in this Section.

in this wave of the survey the questionnaire does not ask whether graduates are employed as researchers and thus we decided not to rely on it in the previous analysis. Table 6 shows that when the outcome variable is the likelihood of being enrolled in a PhD program, our results are largely similar to the previous case (see Table 4). In the more reliable specification — i.e. the one with university fixed-effects — a one-standard-deviation increase in the CIVR score increases the likelihood of enroling in a PhD by about 0.4 percentage points for the whole sample and almost 0.7 percentage points for graduates in science, medicine and engineering. Note, however, that coefficients related to patents and patent citations are not statistically significant. One interpretation is that market-oriented academic research is less related with the pursuit of post graduate degrees than fundamental research.

Table 7 reports the coefficients related to the regression where the left-hand-side variable takes value 1 when a graduate is employed as a researcher.[11] None of the coefficients related to our measures of research quality are significantly different from zero but the ones related to patents. How should we interpret the zero correlation with the main measure of research performance and the positive correlation with patent statistics? The first result may stem from the basic fact that we observe individuals only three years after graduation. If they graduate in departments that offer a doctoral program they enrol in it before getting a job as researchers. To explore this possibility, we rely again only on graduates from institutions and programs that did not offer a PhD. As shown in the third column in Table 5, for these individuals the correlation between the CIVR score and the likelihood of being employed as researcher is indeed positive, although the coefficient is not statistically significant.

As far as the patent result is concerned, as said above, not in all disciplines patents are considered as standard outcomes of academic research activity and, thus, this indicator has to be interpreted with caution. However, our result suggests that graduates from departments that focus more on market oriented research are more likely to enter the labor market for researchers than receiving a PhD.[12]

Note that in this latter regression, we also control for the fact that graduates found their job using recommendations from their university or professors: it is possible that the strength of university-business links is related to the quality of academic research. This control, however, does not affect our basic finding.

[11]Note that the outcome variable assumes value 0 also when a given graduate is doing a PhD.

[12]Note that this is true for researchers working both in the private and in public sectors. Results are not displayed but available upon request.

Table 6: PhDs and academic research quality

	Specification	1	2	3	4	5	6
		All disciplines	Sciences, Medicine and Engineering				
		CIVR score	CIVR score	Publications per professor	Citations per professor	Patents per professor	Patent citations per professor
I	Year, Degree, Individual characteristics	0.038**	0.083**	0.025***	0.003***	-0.207	-0.078
		(0.015)	(0.041)	(0.008)	(0.001)	(0.480)	(0.213)
II	I + University-discipline characteristics	0.040**	0.086*	0.024***	0.003**	0.266	-0.023
		(0.016)	(0.046)	(0.008)	(0.001)	(0.480)	(0.211)
III	II + PhD scholarships per graduate	0.044***	0.098**	0.024***	0.003***	0.260	-0.011
		(0.016)	(0.046)	(0.008)	(0.001)	(0.475)	(0.211)
IV	III + University fixed effects	0.041**	0.095**	0.037***	0.005***	0.134	-0.037
		(0.017)	(0.046)	(0.010)	(0.002)	(0.463)	(0.228)

Notes: OLS estimates. In parentheses - standard errors clustered for graduates from each university department. Number of observations in column 1 is 61527, in columns 2-5 – 29691.
* p-value<0.100, ** p-value<0.050, *** p-value<0.010.
Individual characteristics include gender, age groups, high-school grade, type of the high-school attended, province of residence before university, parents' education. University-discipline characteristics include (log) number of professors, student-professor ratio, (log) number of graduates, ownership control, region of university location.

Table 7: Researchers and academic research quality

		1	2	3	4	5	6
	Specification	All disciplines	Sciences, Medicine and Engineering				
		CIVR score	CIVR score	Publications per professor	Citations per professor	Patents per professor	Patent citations per professor
I	Year, Degree, Individual characteristics	-0.005	0.008	0.005	0.001	1.000***	0.436*
		(0.007)	(0.023)	(0.006)	(0.001)	(0.382)	(0.233)
II	I + University-discipline characteristics	-0.003	-0.000	0.004	0.000	1.132***	0.443*
		(0.007)	(0.025)	(0.006)	(0.001)	(0.368)	(0.229)
III	II + PhD scholarships per graduate, "job-via-university" dummy	-0.003	-0.004	0.005	0.001	1.065***	0.434*
		(0.007)	(0.024)	(0.006)	(0.001)	(0.394)	(0.237)
IV	III + University fixed effects	-0.006	-0.014	0.001	-0.000	1.059***	0.404*
		(0.008)	(0.025)	(0.007)	(0.001)	(0.375)	(0.218)

Notes: OLS estimates. In parentheses - standard errors clustered for graduates from each university department. Number of observations in column 1 is 37086, in columns 2-5 – 16346.
* p-value<0.100, ** p-value<0.050, *** p-value<0.010.
Individual characteristics include gender, age groups, high-school grade, type of the high-school attended, province of residence before university, parents' education. University-discipline characteristics include (log) number of professors, student-professor ratio, (log) number of graduates, ownership control, region of university location.

4.5 Who is undertaking research careers?

To repeat, our findings show that graduates from university departments with better academic research quality are more likely to enter research-oriented careers. If we are willing to interpret this correlation as causal, it follows that an increase in the research quality of departments is an effective channel to increase the share of researchers in total employment. However, from a policy perspective, it is important to check whether the skills of the "marginal" graduates who get into a research career in response to an improvement in the quality of research are different. In other words, we want to explore whether the increase in the quantity of graduates that undertake a research career is likely to have a cost in terms of lower quality.

To investigate this issue, we augment the most complete specification of equation (1) with an interaction term between the indicators of research quality and distinct measures of graduates' performance. Our model becomes:

$$\begin{aligned} \textit{Research career}_{idu} &= \alpha + \beta X_{idu} + \delta E_{du} + \eta \textit{Research quality}_{du} \\ &+ \mu \textit{Research quality}_{du} \textit{Grade}_{idu} + \varepsilon_{idu} \quad , \end{aligned} \tag{2}$$

where *Grade* is either the individual i high school grade or the university grade normalized with respect to university and program. In Italy there exist substantial differences in grading standards across universities and programs (Bagues et al., 2008). Hence, the use of the sheer university grade is an imperfect measure and can be misleading to compare graduates from distinct institutions and programs.

As shown in Table 8 (column 1-4), the interaction term between the CIVR ranking and the two indicators for graduates quality is positive and statistically significant, both when the regression is run on the whole sample and when it is run only on graduates from science, medicine and engineering departments. For robustness, we also replicate the analysis using the number of publications, citations and patents per professor as proxies for academic excellence. As shown in column 5-8, results are very similar. This result suggests that departments with better research performance are especially effective in stimulating research-oriented careers for the brightest.

Table 8: Research careers, quality of graduates and academic research

	1	2	3	4	5	6	7	8
Research indicator	CIVR score				Publications per professor		Patents per professor	
Grade	High school		Relative university grade		High school	Relative university grade	High school	Relative university grade
Disciplines	All	SME	All	SME	SME	SME	SME	SME
Grade	-0.004***	-0.011**	-0.008***	-0.014**	0.001***	0.004***	0.002***	0.006***
	(0.001)	(0.004)	(0.002)	(0.006)	(0.000)	(0.001)	(0.000)	(0.001)
Research indicator	-0.389***	-0.694**	0.030*	0.121**	-0.049	0.039***	-1.810	1.222**
	(0.076)	(0.276)	(0.018)	(0.061)	(0.032)	(0.014)	(2.213)	(0.558)
Research indicator*(Grade)	0.009***	0.016***	0.016***	0.025***	0.002***	0.003***	0.062	0.070
	(0.002)	(0.005)	(0.003)	(0.008)	(0.001)	(0.001)	(0.042)	(0.051)

Notes: OLS estimates. In parentheses - standard errors clustered for graduates from each university department. Number of observations in column 1 and 3 is 37086, in columns 2,4-8 is 16346. SME stands from science, medicine and engineering departments.
* p-value<0.100, ** p-value<0.050, *** p-value<0.010.
All estimations include individual characteristics (gender, age groups, high-school grade, type of the high-school attended, province of residence before university, parents' education), university-discipline characteristics ((log) number of professors, student-professor ratio, (log) number of graduates, PhD scholarships per graduate and university fixed effects), year and degree dummies.

5 Conclusions

Recent policy reports and articles have argued that reforming European universities is crucial to regenerate Europe's innovative capacity and economic performance (Dosi at al., 2006; Aghion at al., 2007; Jacobs and van der Ploeg, 2005). A key reason why a better higher education system is believed to enhance growth is that it is likely to stimulate complementary investments in research and development, thereby fostering technological innovation.

In this paper, we explore whether university research performance affects the amount of human resources allocated to research activity. Exploiting the high heterogeneity in academic excellence across Italian institutions and programs, we find that the quality of academic research — measured in a number of ways — is positively correlated with the likelihood of being in a research-oriented careers three years after graduation.

To rule out the possibility that this correlation stems from important omitted variables we perform two important checks. First, relying on cross-department variation, we include university fixed-effects and show that our basic finding is not due to unobserved university heterogeneity. Second, we replicate the analysis only in those institutions and programs that do not have graduate students. This reduces the possibility that out results are entirely driven by the supply of doctoral programs.

If our measures of academic excellence are indeed orthogonal to other unobserved determinants of the probability of entering a research-oriented career, we can interpret our findings as causal. The policy implication of these results is thus straightforward: together with a better functioning labor market for scientists and researchers, improving the science impact of universities and departments is an effective channel to stimulate research-oriented jobs and careers.

An important issue concerns the external validity of our study. Italy has indeed a peculiar system of higher education and the heterogeneous scientific productivity across individual researchers and institutions is not a common feature to all European countries. In other words, do we expect to find the same results in countries where academic excellence is more evenly distributed across institutions and programs? This paper does not provide a straightforward answer for the above question and further research is needed to check whether the same results hold in other contexts.

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Appendix

Table A-1: Description of the variables

Variables	Description	Source
Individual characteristics		
Age	Dummy variables for each age group	Graduates' Survey
Female	A dummy variable for female respondents	Graduates' Survey
Father's education	Dummy variables father education (Secondary education, higher education diploma, university degree, no answer)	Graduates' Survey
Mother's education	Dummy variables mother education (Secondary education, higher education diploma, university degree, no answer)	Graduates' Survey
Province of origin	Dummy variables indicating the province where an individual resided at the age of 14 (103 Italian provinces and a dummy for foreign residence).	
High-school grade	Final high school grade	Graduates' Survey
University grade	Final university grade. For graduates who received diploma with honors (*cum laude*) it is equal to the maximum grade plus 1: 111.	Graduates' Survey
Type of the high school	Dummies for each type of the high school: scientific lyceum, classic lyceum, technical industrial institute, technical institute for geometers, technical commercial institute, other type of technical institute, techers school of institute, language lyceum, professional institute, art lyceum or institute	Graduates' Survey
Course dummies	Dummy variables indicating the exact degree course attended by an individual in the university, 82 categories.	Graduates' Survey
PhD student	A dummy variable indicating that an individual is currently enrolled in a PhD program	Graduates' Survey
Researcher	A dummy variable indicating that an individual is currently employed as a researcher. Unconditional on employment.	Graduates' Survey
Employed	A dummy variable indicating that an individual is currently employed	Graduates' Survey
Job-via-University	A dummy variable indicating that an individual has found his current job using university or professor recommendations	Graduates' Survey
Department characteristics		
Private university	A dummy variable for private universities	MIUR
Number of professors	Number of tenured professors at the level of university disciplinary area	MIUR
Mean professor age	Average age of university professors at the level of university disciplinary area	MIUR
Student-professor ratio	Number of non-delayed students over the number of professors at the department level	MIUR
Number of graduates	Number of graduates at the level of university disciplinary area	MIUR
PhD scholarships per graduate	Number of PhD scholarships available per the total number of graduates at the level of university disciplinary area	MIUR
Research variables		
CIVR score	A score assigned to each university disciplinary area by the external committee evaluating the quality of academic research	CIVR
Publications	Number of ISI Thompson publications done by professors from a given university and disciplinary area in the period 1995-1999.	ISI and CRUI
Publication citations	Number of ISI Thompson citations received by publications up to 2001.	ISI and CRUI
Patents	Number of all patent applications done by academic inventors from a given university and disciplinary area with the priority date between 1993 and 2001	EPO and KEINS
Patent citations	Number of all citations received by academic patents from other EPO patents up to 2004.	EPO and KEINS

Abbreviations: MIUR is the Italian Ministry of Education and Research. CIVR is the Committee for Evaluation of Research at the Ministry of Education and Research. CRUI is the Conference of Italian University Presidents. EPO is the European patent office. KEINS stands for the the European research project "Knowledge-based Entrepreneurship, Innovation Networks and Systems"

Table A-2: Research careers and academic research quality

	1	2	3	4	5	6
	All	Sciences, Medicine and Engineering				
	CIVR score	CIVR score	Publications per professor	Citations per professor	Patents per professor	Patent citations per professor
Academic research						
CIVR	0.041**	0.120**				
	(0.016)	(0.051)				
Publications per professor			0.030***			
			(0.009)			
Citations per professor				0.004**		
				(0.001)		
Patents per professor					0.869	
					(0.541)	
Patent citations per professor						0.426
						(0.299)
Individual characteristics						
Female	-0.014***	-0.003	-0.003	-0.003	-0.003	-0.003
	(0.003)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
When an individual was 14 years old his fathers highest educational title was:						
- secondary education license	0.001	0.005	0.005	0.005	0.005	0.005
	(0.003)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
- higher education diploma	-0.003	0.002	0.002	0.002	0.002	0.002
	(0.004)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
- university degree	0.014***	0.022**	0.022**	0.022**	0.022**	0.022**
	(0.005)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
- no answer	-0.005	0.012	0.012	0.012	0.011	0.011
	(0.017)	(0.029)	(0.029)	(0.029)	(0.029)	(0.029)
When an individual was 14 years old his mothers highest educational title was:						
- secondary education license	0.000	0.003	0.003	0.003	0.004	0.004
	(0.003)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
- higher education diploma	0.002	0.006	0.006	0.006	0.006	0.006
	(0.004)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
- university degree	0.012**	0.014	0.014	0.014	0.015	0.014
	(0.006)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)
- no answer	0.008	-0.019	-0.019	-0.019	-0.018	-0.018
	(0.020)	(0.025)	(0.025)	(0.025)	(0.025)	(0.025)
High-school grade	0.002***	0.002***	0.002***	0.002***	0.002***	0.002***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Type of the high school	Yes	Yes	Yes	Yes	Yes	Yes
Age groups	Yes	Yes	Yes	Yes	Yes	Yes
Province of origin	Yes	Yes	Yes	Yes	Yes	Yes
Other controls						
Year 1998	Yes	Yes	Yes	Yes	Yes	Yes
Degree dummies	Yes	Yes	Yes	Yes	Yes	Yes
Constant	-0.044*	-0.213***	-0.121***	-0.119***	-0.118***	-0.117***
	(0.026)	(0.055)	(0.034)	(0.033)	(0.033)	(0.034)
R-sq	0.101	0.123	0.122	0.122	0.122	0.122

Notes: OLS estimates. In parentheses - standard errors clustered for graduates from each university department. * p-value<0.100, ** p-value<0.050, *** p-value<0.010. Number of observations in column 1 is 37086, in columns 2-5 – 16346.