Does Teacher Quality Affect Student Performance? Evidence from an Italian University

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Abstract. *In this paper we analyse whether the characteristics of university teaching staff matter with regards students' performance and interest in the discipline. We use data on about one thousand students enrolled on the first level degree course in Business and Economics at a medium sized Italian University. Thanks to the random assignment of students to different teaching sections during their first year, we are able to analyze the effect that teachers with different characteristics, in terms of experience and research productivity, produce both on students' performance, measured in terms of the grades obtained at subsequent exams and courses chosen. Our results suggest that teacher quality has statistically significant effects on students' grades on subsequent courses. These effects are also robust after controlling for unobserved individual characteristics. On the other hand, we find less clear evidence when relating teacher quality to student involvement with a subject. It emerges that more experienced teachers have a negative impact on the probability of a student's undertaking additional courses in a subject, while research productivity does not produce a statistically significant effect.*

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1. Introduction

A large and increasing body of economic literature analyzes educational processes both from a theoretical and from an empirical point of view, trying to understand the role played by factors such as class-size, peer group and teacher quality in the determination of students' results. Starting from the Coleman report (Coleman 1966), the initial findings of this literature showed that peer quality and families are far more important than teacher quality in determining test scores and educational attainment. These conclusions have been challenged by a number of recent works which argue that differences in teacher quality matter with regards students' performance (Card and Krueger, 1992, 1998; Hoxby, 2002; Hoxby and Leigh, 2004; Rockoff, 2004; Rivkin et al., 2005; Jacob and Lefgren, 2005).

Studies analyzing the effect of teaching quality on student performance generally focus on primary and secondary education, while little work has been done to consider post-secondary education, partly because of the lack of data-sets matching student results to teacher characteristics.

Skills acquired by undergraduate students, during their academic experience, are crucial for their success in the labour market and understanding which kind of teacher is more likely to positively affect their human capital accumulation process is crucial in any attempt to improve their performance.

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The few studies trying to disentangle the effect of teacher quality on student performance at post-secondary level use data from US universities. Borjas (2000) and Norris (1991) examine the impact of foreign teaching assistants on the performance of students enrolled respectively at Harvard and at the University of Wisconsin, showing a negative effect. Bettinger and Long (2005) consider a large sample of public universities in Ohio and, using year to year and class-to-class variations in first year teachers, they show that adjuncts increase the probability that students will dropout during the second year[1]. Their study also examines how adjuncts affect the likelihood of enrolment and success in subsequent courses showing that adjuncts and graduate assistant instructors reduce subsequent interest in a subject more than full-time, tenure-track, faculty members do, but also that this effect is small and differs greatly according to discipline. On the other hand, Hoffmann and Oreopoulos (2006) show that, while students' evaluations of the teaching effectiveness of their teachers work well as an appraisal of teachers' influence on students' results, objective characteristics do not seem to play a relevant role.

Our study adds to these works and provides evidence of the effects of instructors' teaching experience and research productivity on the performance of students enrolled on the First-Degree ("Laurea Triennale")[2] course in Business and Economics at the University of Calabria, a middle-sized public university located in the south of Italy. Our data set offers information both on students' university curricula and teachers' characteristics, and, thanks to the random assignment of students to different teaching classes for the same subject , we are able to compare the results of students who were assigned to different teachers in their introductory courses to different subjects.

We use, as a measure of students' performance, the average grade obtained at exams in a given subject, subsequent to the introductory course in that subject. Moreover, we analyse whether students have undertaken additional rather the compulsory courses in the subject. These measures of students' performance allow us to try to take into account both the effect that teachers' characteristics have on learning during a given introductory course, with regards to the importance that this learning has for the work on subsequent related courses, and on students' interest in a given discipline.

While the effect of experience has been examined in other studies, we do not know of any other work focusing on the effect of teachers' research productivity on students' results. This allows us to evaluate whether teaching and research are substitutes or complementary activities and whether it may be optimal to separate them. From a theoretical point of view, the relationship between teaching and research activity can either be positive or negative. On the one hand, more active researchers are also in a better position to transmit academic knowledge, while, on the other hand, people who are highly

[1] Similar results emerge from a study conducted by Ehrenberg and Zhang, 2005.

[2] As we explain below, the Italian University system is organized into two main levels: students first enrol on a First Level Degree course (with a legal duration of three years) and, after graduation, they may choose to enrol on a Second Level Degree course (with a legal duration of two years).

involved in research may have less time to devote to teaching activity and, as a consequence, they may be less effective.

We estimate a simple regression model of grades obtained by students in exams subsequent to introductory courses to the main subjects within their degree programme. From our analysis it emerges that both teacher experience and research productivity produce a positive effect on student performance.

We also obtain similar results when we only consider graduate students, who are more homogeneous in terms of academic curriculum. For these students, considering only subsequent compulsory subjects, we find that an increase of one standard deviation in teacher experience produces an increase in student performance on subsequent courses of 0.12 points, while teacher research productivity shows a coefficient of 0.15.

While our results regarding the full sample may be related to selection in subsequent courses, since our measure of student performance only applies where students have successfully sat at least one subsequent exam in each of the considered subjects, selection problems should be much less severe when focusing on graduate students. In fact, in order to graduate, students are required to take a minimum number of exams in four of the five main subjects we consider. We are confident that, once exclude non-compulsory subjects are excluded, results for this sample of students will not be biased by endogenous selection.

Our main findings also hold true when we exploit the panel nature of our data set and control for individual fixed effects. Fixed effect estimates show slightly smaller coefficients compared with OLS estimates.

Finally, we investigate the effect of teacher characteristics on student choices in terms of subsequent courses. In many cases students choose their courses on the basis of their experience, and, as a consequence, the characteristics of teachers they encountered on the introductory course of to given subject may affect their decision of whether to undertake additional courses in that subject. Since our sample students, after some compulsory courses, have a certain degree of freedom in choosing their curricula, we estimate a probit model for whether students have undertaken additional non-compulsory courses in each subject.

Our results show that more experienced teachers have a negative impact on the probability of student's successfully following additional non-compulsory courses, while research productivity does not have a statistically significant effect. However, these effects are not homogenous across subjects.

The paper is organized in the following way. Section 2 describes data on student curricula and on teacher characteristics and explains the process of assigning students to different teaching classes. Section 3 presents our main results on the effects of teacher quality on students' subsequent grades estimating a simple model using pooled OLS. Section 4 presents fixed effect estimates. Section 5 is devoted to analyzing the effect of teacher characteristics on students' interest in a discipline. Section 6 concludes.

2. Data

Our analysis is based on a rich set of administrative data providing information on undergraduate students enrolled, in 2001 and 2002, on the First-Level Degree course in Business and Economics (BE from here after) at the University of Calabria, a middle-sized Italian public university[3].

The data we have provide detailed information on students' university curricula (year of enrolment, grades obtained on each course etc.) from their enrolment in 2001 and 2002 to December 2006, together with the type of high school attended and final high school grade, gender, and place of residence.

According to the data provided by the faculty administrative office, 905 students enrolled on the BE Degree course in the two years we take into consideration (448 enrolled in 2001 and 457 in 2002), 355 of them graduated (226 of the graduates students enrolled in 2001 and 129 in 2002), while the remaining 550 have not got their degree yet. Table 1 provides some descriptive statistics. About 50% of students are female. They mainly come from two different types of High Schools: Lyceums (34%) and Technical and Vocational Schools (66%), with an average final high school grade of 83.63 (ranging from 60 to 100).

These students have passed an average of 24 exams, with a minimum of 1 and a maximum of 37 in different subjects (plus foreign language classes). The average grade in exams taken is 23.40, with a minimum of 18 and a maximum of about 29.5. In Italy students are evaluated on a scale that ranges from 18 to 30 cum laudem (which we consider as 31), and in order to obtain their first level degree they have to acquire a total number of 180 credits[4].

Students enrolled on the BE Degree course follow a common programme during their first year, taking 11 compulsory courses (listed in table 2), for a total of 55 credits, in different teaching sections. After these common courses[5], students may choose from among a large number of different courses in different disciplines. We classify subsequent courses into six subjects (we discard subsequent courses if the relative introductory course was taught in the second year of the degree programme[6]):

[3] The University of Calabria currently has about 31,000 students enrolled on different degrees courses and at different levels of the Italian University system, which, since 2001, has been organized around three main levels, constituted by First Level degrees (3 years of legal duration), Second Level degrees (2 years) and Ph.D.s. Students who have acquired a First Level degree may undertake a Second Level degree and after this they may do a Ph.D.

[4] For the BE degree we are considering, 180 credits correspond to a total number of about 36 exams (including foreign languages classes for which only the information of whether the student passed or not is available). Students are allowed to take additional exams.

[5] During the second year students attend another 2 compulsory courses organized into two teaching classes.

[6] Introductory courses taught during the second year are not compulsory and are generally taught in a single class.

Accounting and Management, Business and Marketing[7], Economics, Law, Maths and Statistics. As is shown in table 1, the average number of subsequent exams in Accounting and Management (ACC), Business and Marketing (BUS), Economics (ECO) and Law (LAW) is respectively of 3.3, 2.3, 3.4, and 1.6 with an average grade of 24.9, 24.3, 23.9, and 22.3 respectively. The large majority of students take just one additional course in Maths (MAT), with an average grade of 20.88, while only a few students take additional courses in Statistics (STA).

Table 1. Descriptive statistics for the sample of students

Variables	Mean	Std. Dev	Min.	Max.	Obs.
Average grade in exams taken	23.403	2.261	18	29.5	906
Number of exams taken	24.000	11.220	1	37	906
Female	0.517	0.500	0	1	906
High School Type: Lyceum	0.340	0.474	0	1	906
High school final grade	83.633	12.223	60	100	906
Dummy Year of enrolment	0.494	0.500	0	1	906
Peer group ability	86.423	1.065	84.9	88.5	906
Average grade Introductory ACC	23.760	3.126	18	30.5	869
Average grade Introductory. BUS	23.712	3.654	18	31	746
Average grade in Introductory LAW	22.346	2.807	18	30	735
Average grade in Introductory MAT	21.020	2.819	18	30	751
Average grade in Introductory ECO	2.810	3.335	18	31	740
Average grade in Introductory Statistics	23.388	3.184	18	31	845
Subsequent Exams in ACC	3.353	2.234	1	10	762
Subsequent Exams in BUS	2.369	1.487	1	6	607
Subsequent Exams in ECO	3.412	1.769	1	9	687
Subsequent Exams in LAW	1.661	0.923	1	11	558
Subsequent Exams in MAT	1.002	0.050	1	2	397
Subsequent Exams in STA	1.000	0	1	1	16
Average Grade ACC	24.904	3.165	18	31	762
Average Grade BUS	24.301	3.152	18	31	607
Average Grade ECO	23.967	2.833	18	30.5	687
Average Grade LAW	22.316	3.006	18	30	558
Average Grade MAT	20.884	2.962	18	30	397
Average Grade STA	26.875	3.138	20	30	30

While, for compulsory first year courses, students were divided into different teaching classes, all subsequent non-compulsory courses were taught in a single class.

2.1. Teacher Characteristics and the Assignment of Students to Teaching Classes

As a result of the high number of students enrolled on the First Level Degree course in BE, they were assigned to three different teaching classes (Class 1, 2 and 3) for each of the 11 compulsory first year courses on the alphabetic basis of their surnames.

[7] We distinguish Accounting and Management courses from Business and Marketing courses following the codification of disciplinary sectors, respectively SECS-P07 and SECS-P08, as defined by national law.

We use historical university course data to match first year teaching classes with teachers and different data-sets to obtain information on teachers' characteristics. We use Polaris, an on-line documentation system which provides a detailed curriculum for each member of the University of Calabria, to obtain information on teaching experience and position (assistant professor, associate professor, full professor).

Our measure of teaching experience is based on seniority. In fact, we consider as teaching experience the number of years each teacher had been working with a permanent position within the university system, (an academic career starts with the position of assistant professor in Italy), at the time he/she was teaching the introductory course for our sample of students. Since assistant professors are generally required to do some teaching (in the Faculty of Economics of the University of Calabria, they are required to teach at least one course, and a large part of the teaching staff we consider has obtained the position of assistant professor at this university), we think this is an appropriate measure of teaching experience.

In order to gather information on teachers' publications we use a number of datasets such as Econlit, Infolegis, Science Citation Index Expanded and Polaris. Measuring research productivity is not an easy task, especially when dealing with different disciplines. We use two different measures. The first (*Research*) is defined as the ratio between the total number of publications and years of seniority. The total number of publication is that which is indicated respectively by Econlit for economics' teachers, by Science Citation Index Expanded for mathematicians and for teachers teaching statistics, and by Infolegis for law teachers. To measure the research activity of teachers teaching the introductory courses of ACC and BUS, we consider the total number of articles in referred journals as indicated by Polaris, since it was not possible to find other suitable sources[8].

Clearly this measure is mainly based on quantity, since it does not consider differences in quality between different journals or the number of citations. If we take into account the fact that finding appropriate criteria for different disciplines is quite complicated, considering only those articles published in referred journals seems to us an acceptable measurement of quality.

However, we make an attempt to consider journal quality in our second measure of research productivity (*ResearchIF*). This measure is the result of a principal component analysis summarizing the number of articles in referred journals and the impact factor of publishing journals.[9] We only use the first principal component.

[8] Since part of the financial resources obtained by each faculty member (for example Fondi ex 60%) is decided on in relation to the information included in this system, it is in the teachers' interest to update information on their publications.

[9] To each teacher we have attributed the sum of the impact factor of journals publishing his/her research (as indicated on the journals' homepages or in different lists of journal rankings). We also experimented by considering journals ranking and obtained very similar results.

Table 2 provides descriptive statistics for the characteristics of the teachers teaching the compulsory components of the first year degree course in BE. In a few cases, two teachers co-taught a class on a course and, in these cases, the teachers' characteristics are averaged over both and the pair is considered as one teacher. 36% of teachers teaching first year compulsory courses have 10 or more years teaching experience, 32% of them have experience of between 4 and 9 years and 32% of them have less than 4 years of experience. Teachers with greater teaching experience are responsible for the introductory courses of STA, LAW, MAT and ACC. There are also relevant differences among teachers within the same subject. In fact, teaching experience presents a high standard deviation for ECO, MAT and ACC. Teachers also differ in terms of research productivity. When research productivity is measured using *Research*, the larger differences within the same subject are observed among teachers teaching in MAT, BUS and ECO, while, when we use *ResearchIF*, the greatest differences emerge among teachers teaching in MAT, STA and ECO. As far as rank positions are concerned, 33% of teachers are assistant professors, 56% of them are associate professors and 11% are full professors.

Table 2. Common First Year Exams and Descriptive Statistics for Teachers

Course	*Number o*	*Teaching Experience*				*Research Productivity*				*Research ProductivityIF*			
	Teachers	Mean	St. De	Min	Max	Mean	St. De	Min	Ma	Mean	St. Dev	Min	Ma
Management 1 and 2, ACC 10 credits	6	7.25	4.33	2	14	0.24	0.18	0.00	0.50	-0.73	0.05	-0.77	-0.65
Business Administration 1 and 2, BUS, 5 credits	3	2.33	1.58	1	4	0.75	0.25	0.50	1.00	-0.84	0.04	-0.89	-0.77
Economics 1and 2, ECO, 10 credits	3	6.33	5.86	2	13	2.67	2.75	0.00	5.50	-0.02	0.67	-0.90	0.67
Private Law 1 and 2, LAW 10 credits	3	9.50	1.50	8	11	0.76	0.47	0.25	1.18	-0.78	0.09	-0.84	-0.61
Mathematics 1 and 2, MAT 10credits	3	7.33	9.29	1	18	3.93	3.81	0.44	8.00	1.21	1.94	-0.52	3.73
Statistics 1 and 2, 10 credits	4	11.7	6.11	5	20	0.63	0.18	0.40	0.91	1.16	1.17	-.08	3.54

As said before first year compulsory courses where taught in different teaching classes and students were assigned to these teaching classes on the basis of their initials. To avoid congestion in the classrooms that would have been generated by students wanting to attend lectures with their friends or with the best teachers, this assignment of students to classes was binding and was enforced through various methods. First, lectures were supposed to circulate attendance sheets for students to sign. In addition, administrative records for passed exams were divided in relation to teaching classes and students were only supposed to register exams with the teachers responsible for their assigned teaching classes. Most importantly, since, in spite of common programmes, final exams were defined and marked autonomously by each teacher, students were highly interested in respecting their class assignation. On the other hand, given the large number of students in each class, teachers were also interested in enforcing the class divisions assigned in order to avoid overcrowded classrooms.[10]

This guarantees to us that students were not in a condition to choose their teaching classes according to the teachers and that the administration's assignment of students to the different teaching classes correctly matches students to their teachers.

To confirm the randomness of the mechanism of assignment of students to teachers we regress individual ability (measured by the final grade obtained at high school) on teacher characteristics and additional controls, which include a gender dummy and a dummy for the type of high school attended. If students are sorted between teachers on the basis of ability, then the coefficient of teachers' experience and research productivity should be positive and statistically significant.

Table 3 presents the results of this regression for the full sample and for the sample of graduate students. It turns out that in every case we reject the hypothesis that the conditional correlation between individual and teacher quality is not statistically significant. The same results hold true (as shown in columns 5 and 6) when we only consider students for whom we are able to observe our dependent variable (grades in subsequent courses). As students are more likely to take subsequent exams in certain subjects rather than in others (due to the requirements of their degree programme), in columns 5 and 6 we also control for subject dummies.

Table 3. Endogeneity checks. Dependent Variable: final high school grade

	1	2	3	4	5	6
Experience	0.008	0.010	0.011	0.012	0.008	0.018
	(0.013)	(0.013)	(0.015)	(0.015)	(0.015)	(0.020)
Research	-0.007		0.001			
	(0.007)		(0.005)			
ResearchIF		0.005		0.008	0.001	-0.078
		(0.007)		(0.010)	(0.015)	(0.079)
Gender Dummy	YES	YES	YES	YES	YES	YES
Type of High School	YES	YES	YES	YES	YES	YES
Subject dummies					YES	YES
R-squared	0.09	0.09	0.12	0.012	0.08	0.012
Observations	5436	5436	2130	2130	2985	1381
Students	905	905	355	355	792	355

Notes: Standard errors (corrected for heteroskedasticity) and incorporating clustering grouped by student are reported in parentheses.

[10] Students who wanted to change their assigned teaching class had to make an explicit request to the President of the Degree Course. The change was only accorded to students who provided documentation showing that they were unable to attend lectures with the assigned teaching class. However, in order to be able to effectively organize teaching activities, these requests were usually rejected. Moreover, since our sample students were full time students, it was difficult for them to provide "acceptable" motivation of their request.

However, it is worthwhile noticing that the assignment mechanism described above is not as clean as a true experiment, since students could be aware of teachers' reputations and of their own probability of being assigned to them and react to this information, for example deciding not to enrol. We are confident that this problem is not particularly relevant to our case, since the BE degree course started in 2001 (with the reform of the Italian university system) and at least our first cohort of students had no information about the assigning of teachers to teaching classes. Moreover, each teaching class may be characterized by good lecturers in certain subjects and poor lecturers in other subjects[11].

On the other hand, relevant problems may emerge in relation to the reactions of students to teacher quality after assignment. For example, they may react to teacher quality by dropping out of the class and, then, being unable to take subsequent courses in that subject, or by deciding not to take subsequent courses in that discipline[12]. As we will discuss later, these reactions pose important selection issues.

3. Teacher Quality and Students' Average Grades

A typical measure of success at university is represented by the average mark obtained at exams. As shown in the previous section, the students we consider obtained an average grade of 23.40, ranging between 18 and 29.5, over an average number of 24 exams (corresponding to 120 credits). These variations depend on differences in student abilities and in the degrees of difficulty of different programmes undertaken by students, but they also reflect differences in knowledge acquired during their academic career.

In this section we investigate whether having attended introductory courses in different teaching classes taught by teachers with different characteristics produces any effect on students' results in terms of average grades obtained at subsequent exams. More precisely, as knowledge acquired on introductory courses is generally relevant regarding student performance on subsequent courses, we analyse the impact of having attended an introductory course in a given subject with an teacher with certain characteristics on the average grade that students obtain in subsequent exams in that subject. We focus our attention on the six subjects, the introductory courses to which were taught during the first year degree programme (ACC, BUS, ECO, LAW, MAT, STAT).

[11] The allocation of teachers to teaching classes was decided upon autonomously by teachers teaching the courses. For example, teachers teaching the introductory course of economics decided to follow the same rules established for students and to teach classes according to the initials of their surnames.

[12] However, as shown above, even when we only consider students who did not drop out of introductory courses and who took subsequent exams in the considered subjects, there does not appear to be a correlation between teacher quality and students' predetermined ability.

Letting i indicate students and f subjects, we define our dependent variable g_{if} as the average grade obtained by student i in subject f. More precisely, we consider the average grade obtained by student i in the e_{if} exams he successfully takes in subject f, after having attended an introductory course in that subject, so that $g_{if} = \frac{1}{e_{if}} \sum_{k=1}^{e_{if}} G_{ik}$, where e_{if} are the exams taken by i in subject f and Gi_k is the grade obtained by student i in the exam k in subject f.

We start by estimating, using pooled Ordinary Least Squares (OLS), the following simple model:

$$[1] \qquad g_{if} = \beta_0 + \beta_1 X_{if} + \beta_2 Exp_{if} + \beta_3 Res_{if} + \beta_4 Grade_{if} + \mu \qquad f = 1,....F$$

where X_i represents a vector of individual characteristics including final high school grade, a dummy for the type of high school (*Lyceum*), a gender dummy (*Female*). We also include the grades obtained by the student on the introductory course in subject *f*. However, in order to take into account different evaluation methods that may have been adopted by different teachers, we introduce into our estimates the ratio between the grade obtained by student *i* on the introductory course in subject *f* and the average grade obtained by all other students attending that introductory course with the same teacher (*Relative Grade*). Exp_{if} and Res_{if} are variables measuring respectively the teaching experience and the research productivity of teachers teaching on the introductory courses of subject *f* to student *i*. In order to take into account the level of difficulty of the different subsequent courses chosen by each student in a given subject (or different evaluation criteria used by teachers), we control in each regression for the average grade ($Grade_{if}$) obtained by all other students taking a given exam and consider the average from all exams taken by student *i*. μ is an error term.

We have also included a dummy variable for each subject and another for the year of enrolment. All equations include a constant and dummies for the student's province of residence (not reported to save space). Standard errors (reported in parentheses) are corrected for heteroskedasticity and as some of the regressors vary at student level, in order to avoid biased standard errors, we estimate our models clustering the standard errors at this level (Moulton, 1990).

All variables have been standardized in order to make results comparable in different specifications and to render the interpretation of marginal effects more straightforward.

In Table 3 we report estimates of different specifications of our model. In column 1, we first estimate an equation with no reference to teaching quality so as to check which factors determine academic performance. We show that our measures of predetermined ability, respectively the relative grade obtained on the introductory course in the subject and the grade obtained at high school, are positive and highly significant. *Grade* is positive and significant implying that students who take less difficult courses obtain higher grades. Students who have attended a lyceum perform better. The female dummy is not significant and nor are the dummies for different subjects (with the exception of Statistics). The dummies for province of residence are generally not significant.

The other columns in Table 3 include variables measuring teacher characteristics. In all specifications, it emerges that, controlling for student ability and characteristics, teacher experience and research productivity produce a positive effect on student performance in subsequent courses.

As it is possible to see in column 2, an increase of one standard deviation in teacher experience leads to an improvement of student performance of about 0.15.[13] On the other hand, an increase of one standard deviation in teacher research productivity, measured by *Research*, leads to an improvement of student performance of about 0.20. As shown in column 3, the effect of research productivity is smaller when we use our *ResearchIF* measure: the coefficient is about 0.17.

The other explanatory variables have approximately the same level of significance as in column 1. However, some of the subject dummies are now significant. It emerges that our sample students obtain better grades in ACC, STA and BUS compared with ECO, while they obtain worse grades in MAT.[14]

As only a few students take additional exams in Statistics (STA), we have also experimented with considering the effect of teachers teaching the introductory course in statistics in terms of the average grade obtained on subsequent courses in ECO and MAT. As it is possible to see in column 1 of Table 1A (in the Appendix), coefficients attracted by *Experience* and *Research* are positive and statistically significant at the 1% level, but smaller compared to those discussed previously.

Results shown in Table 2A in the Appendix, separately presenting estimates for the main disciplines (ACC, BUS, LAW, ECO and MAT), suggest that the former three subjects and the latter two subjects are relatively homogeneous as far as teacher quality effects are concerned. Then, in Columns 4 and 5 of Table 3, we present estimates separately for two groups of disciplines (using

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[13] To analyse the effect of experience we also experiment with defining a dummy variable equal to 1 for teachers with more than 4 years teaching experience. We obtain substantially the same results: the coefficient is significant at a 1% level and having attended the introductory course with an teacher with more than 4 years experience increases students average grade in this subject by 0.16 points. The coefficient is 0.15 when we only consider graduate students.

[14] Our result does not change if we introduce among regressors demographic characteristics of the area in which the student's family lives and in which the student attended high school, such as the percentage of people leaving school in student i's area of residence with a college or a high school diploma, income in the community of residence, and the unemployment rate in the area. These factors are not statistically significant. Unfortunately, we do not have information on the students' family income. However, we think that the type of high school attended is a good proxy of family income, since students from richer families generally enrol at Lyceums (Brunello and Checchi, 2006).

Research as measure of research productivity). The first group includes ACC, BUS, and LAW, while the second group includes ECO, MAT and STA (for the latter we have only a few observations).[15]

From our analysis it emerges that research productivity is relevant for the second group of subjects, but it is not statistically significant for the first group. On the other hand, teaching experience is especially relevant for ACC, BUS and LAW. The other explanatory variables have the same level of significance as in the other specifications, with the exception of the female and the lyceum dummies, which are positive and statistically significant for the group of subjects including ECO, MAT and STA.

One may question whether our results might be related to selection of subsequent courses. In fact, we observe the dependent variable g_{if} only if students have successfully completed at least one course in subject *f*, while we do not observe students who did not pass at least one exam, possibly because they are behind schedule in their university careers for random factors, because they have decided not to take additional courses in that discipline (when this is allowed by their degree programme) or because they are still trying to pass the introductory course in that subject[16].

As a consequence, students who have successfully taken at least one exam after the introductory course in a given subject and for which we observe the dependent variable may not result randomly selected and error term in [1] may be correlated with the selection of individuals in the sample. For instance, if only the more motivated students who have attended introductory courses with more experienced and more research productive teachers take future courses in that subject (maybe because only these students have passed the introductory class exam), then the positive sign of these variables might be related to unobserved factors which influence both the average grade obtained and the probability of being in the sample. Moreover, students who do not acquire a sufficient level of knowledge on introductory courses may not be able to pass subsequent exams in those subjects. Since acquired knowledge is influenced by teachers, our sample may be selected in relation to teachers' characteristics.

These problems are much less severe if we only consider graduate students. In fact, in order to graduate students are required to take a minimum number of exams in four of the subjects we consider (ACC, BUS, ECO and LAW). For these students, restricting the analysis to compulsory subjects, we are able to avoid problems deriving from missing values in our dependent variable.[17]

In column 6 we present results for this sample of students in all subjects and, in column 7,

[15] Nothing relevant changes if we exclude STA from the second group of subjects.

[16] Unfortunately, we only have data on passed exams, as no information is available with regards to failed exams.

[17] We may still have selection problems if the probability of graduation is related to teacher quality, however since students assigned to each first year teaching class encounter a number of different teachers of differing quality, effects produced by a good teacher should be compensated for by those produced by a bad one. Probit estimates analysing whether the probability of graduation is affected by the characteristics of teachers teaching first year courses do not show any significant effect.

results for graduate students are reported considering only compulsory subjects. The statistical significance of regressors does not change much, but we observe smaller effects. As shown in column 7, where we only consider the performance of graduate students in compulsory subjects, an increase of one standard deviation in teacher experience produces an increase of 0.12 in student performance, while the effect observed for teacher research productivity is of 0.15[18].

Table 4. OLS regression estimates for students' academic achievement

Explanatory Variables	1	2	3	4	*5*	6	7
High school final grade	0.240***	0.239***	0.238***	0.290***	0.138***	0.194***	0.200***
	(0.021)	(0.021)	(0.021)	(0.025)	(0.031)	(0.028)	(0.031)
Relative Grade	0.320***	0.32***	0.321***	0.329	0.306** *	0.269***	0.276***
	(0.019)	(0.017)	(0.017)	(0.020)***	(0.027)	(0.022)	(0.023)
Grade	0.413***	0.415***	0.416***	0.419***	0.428***	0.455	0.451***
	(0.055)	(0.055)	(0.055)	(0.066)	(0.119)	(0.074)***	(0.075)
Lyceum	0.056***	0.057	0.056***	0.039	0.087***	0.048**	0.043*
	(0.019)	(0.017)***	(0.018)	(0.021)	(0.024)	(0.022)	(0.022)
Female	0.026	0.024	0.025	0.004	0.056**	0.047**	0.048**
	(0.019)	(0.018)	(0.019)	(0.022)	(0.025)	(0.025)	(0.027)
BUS	0.006	0.091***	0.077***			0.078***	0.073***
	(0.015)	(0.022)	(0.022)			(0.025)	(0.027)
MAT	-0.060	-0.111***	-0.145***		-0.074	-0.115*	
	(0.046)	(0.047)	(0.050)		(-0.095)	(0.063)	
ACC	0.006	0.06***	0.039**	-0.058*		0.117***	0.110***
	(0.017)	(0.020)	(0.019)	(0.026)		(0.023)	(0.025)
LAW	-0.025	0.001	-0.011	-0.117***		-0.012	-0.021
	(0.028)	(0.029)	(0.029)	(0.041)		(0.040)	(0.041)
STA	0.381***	0.277***	0.317***		0.334** *	0.316***	
	(0.065)	(0.069)	(0.066)		(0.080)	(0.065)	
Year of enrolment	0.029	0.014	0.015	-0.003	0.033	-0.023	-0.020
	(0.018)	(0.018)	(0.018)	(0.024)	-1.29	(0.024)	(0.025)
Experience		0.146***	0.139***	0.202***	0.054*	0.115***	0.120***
		(0.031)	(0.033)	(0.042)	(0.027)	(0.037)	(0.040)
Research		0.196***		0.069	0.090**	0.173***	0.150***
		(0.040)		(0.35)	(0.040)	(0.049)	(0.059)
ResearchIF			0.174***				
			(0.042)				
R-squared	0.40	0.41	0.41	0.38	0.43	0.50	0.44
Observations	2985	2985	2985	1919	1066	1659	1381
	792	792	792	782	677	355	355

Notes: Standard errors (corrected for heteroskedasticity) and incorporating clustering grouped by student are reported in parentheses. The symbols ***, **, * indicate that coefficients are statistically significant, respectively, at the 1, 5, and 10 percent level.

Since teaching sections may also differ in terms of student composition, in the estimates (column 2 of Table 1A, in the Appendix) we have also considered peer group quality, which we measure considering all students attending the same teaching class as a peer group and calculating peer group ability as the average ability (using final High school grades) of these

[18] Very similar results emerge when we use *ResearchIF* as a measure of research productivity.

students[19]. Coefficients of variables measuring teacher quality do not change compared to those reported in Table 3. Peer quality does not seem to produce any relevant effect possibly because our measure of peer group is a coarse one and may not be able to describe the student peer group adequately [20].

We also experimented with introducing dummy variables for teacher rank position (respectively for full and associate professors and taking as assistant professors a benchmark case). As shown in column 3 of Table 1A, in the Appendix, only the dummy for full professor is positive and significant at 5% level. While our measure of research productivity is positive, but not statistically significant.

In conclusion, from our estimates it emerges that both teacher experience and research productivity play a role in shaping student performance. Effects are not small if we compare them with the effects produced by the student's pre-determined ability.

4. Fixed effect estimates

Estimating equation [1] using ordinary least square (OLS) regressions only produces unbiased estimators if unobserved individual characteristics are uncorrelated with the explanatory variables used. Since students in our sample were randomly assigned to first year teaching classes, this assumption should hold true. However, as we are able to observe student performance in different subjects, we exploit the panel structure of the data and estimate the model by fixed effects.

The error term μ in equation [1] can be expressed as $\mu = a_i + \varepsilon_{if}$ where a_i is an unobserved individual effect which is constant across different disciplines and ε_{if} is an idiosyncratic error term. When we take deviations from a student's mean, all individual, observed and unobserved, invariant, fixed effects drop out, allowing us to remove the bias which may occur, because of the omission of the student fixed effect, in estimating the coefficients of interest.

The fixed effect transformation leads to the following expression:

[2]

$$g_{if} - \overline{g_i} = \beta_1\left(X_{if} - \overline{X_i}\right) + \beta_2\left(Exp_{if} - \overline{Exp_i}\right) + \beta_3\left(\Pr od_{if} - \overline{\Pr od_i}\right) + \beta_4\left(Grade_{if} - \overline{Grade_i}\right) + \left(\varepsilon_{if} - \overline{\varepsilon_i}\right)$$

$f = 1, \ldots, F$, where $\overline{g_i} = F^{-1} \sum_{f=1}^{F} g_{if}$, $\overline{x_i} = F^{-1} \sum_{f=1}^{F} x_{if}$ and so on for the other variables.

We write expression [2] as:

[19] On the relevance of peer-group effects see for example Sacerdote, 2001 and Zimmerman, 2003.

[20] Our measure of peer group is aimed at capturing different teaching environments. However, our teaching sections are quite similar in terms of students' average abilities.

$$g_{if}\,\hat{} = \beta_1 X_{if}\,\hat{} + \beta_2 Exp_{if}\,\hat{} + \beta_3 \Pr od_{if}\,\hat{} + \beta_4 Grade_{if}\,\hat{} + \varepsilon_{if}\,\hat{}$$

The assumption of exogeneity now means that the idiosyncratic error ε_{if} in each discipline performance equation is uncorrelated with the explanatory variables in all equations.

In Table 5 we present the within-groups estimates of the student performance specification. These estimates are based on how changes in student performance are related to changes in teacher characteristics. All the individual-invariants are eliminated by the data transformation, leaving just the subject dummies, the relative grades obtained on the introductory courses of the different subjects, the variable *Grade* and teacher experience and research productivity.

The findings are broadly consistent with those presented in Table 4 in terms of sign and statistical significance, but the size of the effects changes substantially for some variables. The F test rejects the null hypothesis that all individual unobservables are identical, with a p-value of 0.000. On the other hand, the correlation between a_i and our regressors, is very small and equal to -0.021.

We observe a considerably smaller coefficient for the relative grade compared to OLS estimates and a larger coefficient for Grade (now denoted by *Grade^* and representing the change in *Grade* from the individual mean across subjects).

Table 5. Fixed effects estimates for students' academic achievement

Explanatory Variables	1	2	3
*Relative Grade^*	0.112***	0.113***	0.117***
	(0.018)	(0.018)	(0.025)
*Grade^*	0.479***	0.481***	0.473***
	(0.049)	(0.049)	(0.067)
BUS	0.087***	0.079***	0.065**
	(0.022)	(0.022)	(0.029)
MAT	-0.084*	-0.120***	
	(0.044)	(0.047)	
ACC	0.072***	0.057***	0.106***
	(0.20)	(0.019)	(0.027)
LAW	0.015	-0.004	-0.029
	(0.027)	(0.027)	(0.038)
STA	0.198***	0.228***	
	(0.076)	(0.075)	
*Experience^*	0.116***	0.112***	0.101***
	(0.031)	(0.033)	(0.042)
*Research^*	0.186***		0.128**
	(0.040)		(0.061)
ResearchIF ^		0.173***	
		(0.040)	
R-squared	0.43	0.43	0.45
Observations	2985	2985	1381
Students	792	792	355

Notes: The symbols ***, **, * indicate that coefficients are statistically significant, respectively, at the 1, 5, and 10 percent level.

Again, results confirm that teacher characteristics matter. As it is possible to see in columns 1 and 2, once we control for individual unobserved effects, a change in teacher experience produces a change in student performance respectively of 0.12 and of 0.11 in the two specifications (the coefficient was respectively 0.15 and 0.14 in OLS estimates). The effect of changes in research productivity is of about 0.19 when using *Research* (column 1) and of about 0.17 when using *ResearchIF* (column 2), similar to the effects found using OLS.

Since our panel is unbalanced, selection problems might still cause biased estimators (Wooldridge 2002). Therefore, in column 3 we focus our attention only on graduate students taking compulsory subjects[21]. The coefficient for *Exp^* is 0.10, significant at a 1% (in OLS estimates it was 0.12), while for research productivity (*Res^*), using *Research*, we observe a coefficient of 0.13, significant at a 5% level, which is lower than the coefficient estimate in OLS of 0.15.

The results of fixed effect estimations allow us to conclude that, after controlling for individual fixed effects too, teacher quality in terms of experience and research productivity has significant effects on student performance in subsequent courses.

5. The impact of teacher characteristics on student interest in a discipline

In this section we examine the relative impact of teacher characteristics on student involvement in a subject. In fact, since students generally choose their courses on the basis of their experience, the characteristics of teachers they encounter on the introductory course for a given discipline may affect their decisions in terms of courses chosen

We simply consider graduate students because only for them do we have clear information about choices made. For students who are still trying to complete their academic career we look at exams that they have passed so far, but we do not have information on exams that they intend to take in the future.

Moreover, since students enrolled on the first-level degree course are required to attain a minimum number of credits for each subject, their choice is limited with regards to additional credit hours.[22] As a consequence, we analyze the impact of teacher characteristics on students' choosing to attend additional courses in each subject. Our dependent variable has value 1 when students take a

[21] In this case the few missing values we observe are related to aspects which are not correlated with the idiosyncratic errors (probably due to students following special programmes).
[22] After introductory courses, students are free to choose from among a large number of different exams, however they are required to pass a minimum number of exams for each field.

number of exams above the minimum number required by their degree programme and 0 otherwise. We estimate by Maximum Likelihood the following probit model:

[3] $$P(A=1 \mid x) = \phi(\beta_0 + \beta_1 X_{if} + \beta_2 Exp_{if} + \beta_3 \mathrm{Re}\, s_{if} + \beta_4 Grade_{if})$$

Our estimates are reported in Table 6. As shown in column 1, the probability of successfully taking exams in a particular subject which are additional with respect to the minimum compulsory number is positively affected by the relative grade obtained on the introductory course to that subject. Moreover, students are more likely to take additional non-compulsory courses in less difficult subjects (the variable Grade is positive and statistically significant).

Table 6. Probit estimates for additional non-compulsory exams

Explanatory Variables	*1*	*2*	*3*	*4*
High school final grade	-0.002	-0.002	-0.044**	0.034*
	(0.014)	(0.014)	(0.019)	(0.020)
Relative Grade	0.038***	0.038***	0.090***	0.011
	(0.015)	(0.015)	(0.021)	(0.019)
Grade	0.848***	0.848***	1.742***	-0.027
	(0.073)	(0.073)	(0.229)	(0.088)
Lyceum	0.006	0.006	-0.028*	0.048***
	(0.010)	(0.010)	(0.017)	(0.014)
Female	-0.013	-0.013	-0.018	-0.001
	(0.010)	(0.010)	(0.019)	(0.014)
BUS	0.006	0.006	0.314***	
	(0.026)	(0.026)	(0.042)	
MAT	0.826***	0.826***		0.116
	(0.061)	(0.061)		(0.072)
ACC	-0.133***	-0.133***		
	(0.025)	(0.025)		
LAW	0.307***	0.307***	1.009***	
	(0.036)	(0.036)	(0.151)	
Year of enrolment	0.014	0.014	0.035	0.042
	(0.010)	(0.010)	(0.021)	(0.015)
Experience	-0.061**	-0.061**	-0.011	-0.091*
	(0.029)	(0.029)	(0.044)	(0.053)
Research	-0.003		-0.48*	0.037
	(0.040)		(0.253)	(0.062)
ResearchIF		-0.002		
		(0.034)		
Log pseudo-likelihood	-969.37	-969.37	-441.74	-428.34
Pseudo R-squared	0.191	0.191	0.379	0.088
Observations	1733	1733	1029	704
Students	355	355	335	355

Notes: In all regressions marginal effects are reported. All regressions include a constant and dummies for the student's province of residence. Standard errors (corrected for heteroskedasticity) and incorporating clustering grouped by student are reported in parentheses. The symbols ***, **, * indicate that coefficients are statistically significant at the 1, 5, and 10 percent level respectively.

Having attended the introductory course in a given subject with more experienced teachers reduces the probability of taking additional non-compulsory courses in that subject. The reduction in the probability of taking subsequent courses is of 6%. Research productivity does not seem to produce any statistically significant effect either when we measure it with *Research* (column 1) or when we use *ResearchIF* (column 2).

When we run separate regressions for BUS, ACC and LAW and for MAT and ECO, as shown in columns 3 and 4 (respectively for the first and the second group of disciplines), we find that the negative effect of experience is statistically significant only for MAT and ECO, while, for the first group of subjects, the effect of research productivity is negative and statistically significant.[23]

From these estimates it is also possible to see that students who have attended a lyceum are less likely to take additional courses in the first group of subjects while they are more likely to take additional courses in ECO and MAT. Students characterized by higher final high school grades behave in a similar way. Having obtained a higher final high school grade increases the probability of taking additional courses with respect to the minimum compulsory number in ECO and MAT, while the effect is negative for ACC, BUS and LAW. On the other hand, the relative grade obtained on the introductory course only produces a statistically significant effect for the latter group of subjects.

6. Concluding Remarks

Policymakers and researchers often debate on teaching and research quality and many countries are moving toward systems that establish a link between the quality of higher education and funding. Systems ranking universities in terms of research productivity and teaching effectiveness, initially adopted by few countries, are now also being embraced by countries which have traditionally been less keen on this kind of scheme. In Italy, the first research evaluation exercise was completed under the guide of an independent body of experts appointed by the responsible government minister (CIVR Comitato di Indirizzo per la Valutazione della Ricerca) in December 2005. Teaching activity is also evaluated according to a set of measures related to didactics (MIUR, 2001 and 2006).

In order to offer better teaching, universities and colleges need to know which factors are more likely to affect student performance. However, little is known about what kind of inputs play a major role in augmenting knowledge acquired by undergraduate students. In fact, while there is much economic literature on teacher quality and on its effect on students' performance in primary and secondary education, not much work has been done to analyse these issues at post-secondary level.

In this paper, using a rich administrative data set providing information on undergraduate students who initially enrolled on the First-Level Degree course in Business and Economics at the University of

[23] We also experimented with estimating a logit fixed effect model and obtained similar results to those shown in Table 5.

Calabria in 2001 and 2002, we have analyzed the impact of teacher experience and research productivity on student results. Students enrolled on this degree course follow a common first year programme, but attend lectures in different randomly assigned teaching classes. This allows us to compare results obtained by students who attended introductory courses with different teachers.

From our analysis it emerges that teachers with higher experience tend to positively affect the accumulation of students' human capital measured in terms of the average mark obtained at subsequent exams in a given field. A positive effect also emerges for teachers' research productivity, pointing to a complementarity relationship between research activity and teaching effectiveness. Teacher quality effects are not small if we compare them to the effects produced by variables describing individual predetermined ability. For example, if we take the ratio of the coefficient of teacher experience to the coefficient of student final high school grade, we find that it is equal to 0.6.

On the other hand, we find less clear evidence of the effects of teacher characteristics on student involvement with a subject. Research productivity does not seem to produce any statistically significant effect, while more experienced teachers have a negative impact on the probability of students' taking additional courses in a subject. This effect is not, though, homogenous across different subjects.

The positive effect of teacher quality on students' grades in subsequent courses emerging from this work suggests that recent trends towards hiring young teachers, who are often inexperienced and not involved in research, may negatively affect student performance. Nevertheless, as these findings pertain to just one university and to teachers who teach first year classes, it is not possible to derive general conclusions and additional research is necessary in order to understand effectively what kind of teachers are more likely to influence student performance.

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Appendix

In column 1 of Table 1A, we considered ECO and MAT as subsequent courses affected by the quality of teachers teaching the introductory course in Statistics. In column 2, Table 1A, considering only graduate students and compulsory subjects, we control for peer quality. In column 3, Table 1A, we introduce dummy variables for teachers' hierarchical positions (for full and associate professors, taking assistant professors as a benchmark case).

In table 2A estimates are reported for each subject separately. We excluded STA due to the low number of observations.

Table 1A. OLS regression estimates for academic achievement

Explanatory Variables	1	2	3
High school final grade	0.244***	0.194***	0.199***
	(0.022)	(0.032)	(0.031)
Relative Grade	0.313***	0.279***	0.277***
	(0.017)	(0.024)	(0.023)
Grade	0.420***	0.453***	0.444***
	(0.053)	(0.075)	(0.075)
Lyceum	0.066***	0.042*	0.043*
	(0.018)	(0.022)	(0.022)
Female	0.031	0.049*	0.047*
	(0.019)	(0.026)	(0.026)
BUS	0.048***	0.072***	0.015
	(0.017)	(0.027)	(0.021)
MAT	-0.089***		
	(0.048)		
ACC	0.036***	0.109***	0.074***
	(0.018)	(0.025)	(0.025)
LAW	-0.011	-0.019	-0.041
	(0.029)	(0.041)	(0.041)
STA	-0.161***		
	(0.022)		
Year o enrolment	0.035*	-0.032	-0.014
	(0.018)	(0.027)	(0.025)
Experience	0.062***	0.115***	
	(0.022)	(0.040)	
Research	0.105***	0.148***	0.033
	(0.024)	(0.059)	(0.052)
Peer Quality		0.031	
		(0.025)	
Full_Professor			0.162**
			(0.069)
Associate_Professor			0.002
			(0.048)
R2	0.40	0.44	0.44
Observations	3364	1381	1381
Students	792	355	355

Notes: In all regressions a constant and dummies for students' province of residence are included. Standard errors (corrected for heteroskedasticity) and incorporating clustering grouped by student are reported in parentheses. The symbols ***, **, * indicate that coefficients are statistically significant at the 1, 5, and 10 percent level respectively.

Table 2A. OLS regression estimates for academic achievement in each subject. Dependent variable: Average Grade in Same-Subject Courses

Explanatory Variables	*ACC*	*BUS*	*ECO*	*LAW*	*MAT*
High school final grade	0.295***	0.395***	0.141***	0.263***	0.168***
	(0.055)	(0.014)	(0.046)	(0.036)	(0.068)
Relative Grade	0.481***	0.249***	0.395***	0.297***	0.278***
	(0.047)	0.030	(0.036)	(0.084)	0.032
Lyceum	0.018	0.161***	0.123***	0.023***	0.085***
	(0.028)	(0.033)	(0.014)	(0.005)	(0.007)
Female	0.026	0.057 **	0.087***	-0.064	0.015
	(0.023)	(0.026)	(0.020)	(0.066)	(0.048)
Grade	0.432**	-0.003	0.496***	0.465***	
	(0.176).	(0.019)	(0.114)	(0.004)	
Experience	0.074**	0.029**	0.050*		0.093*
	(0.019)	(0.010)	(0.026)		(0.037)
Research	-0.770*	-0.024**	0.072***	-0.006	0.136**
	(0.257)	(0.008)	(0.003)	(0.004)	(0.018)
Year of enrolment	0.104***	0.072	0.049	-0.147***	0.015
	(0.017)	(0.063)	(0.017)	(0.028)	(0.023)
R^2	0.447	0.322	0.346	0.220	0.149
Observations	759	342	656	557	394

Notes: In all regressions a constant and dummies for students' province of residence are included. Standard errors (corrected for heteroskedasticity) and incorporating clustering grouped by teacher are reported in parentheses. The symbols ***, **, * indicate that coefficients are statistically significant at the 1, 5, and 10 percent level respectively.