The Impact of Teacher Qualification on students' achievement: Evidence from Portuguese Schools

I. Pedroso
Nova School of Business and Economics,
Universidade Nova de Lisboa

A. B. Reis
Nova School of Business and Economics,
Universidade Nova de Lisboa

L. C. Nunes
Nova School of Business and Economics,
Universidade Nova de Lisboa

M. C. Seabra
Nova School of Business and Economics,
Universidade Nova de Lisboa

An administrative dataset from Portugal was used in order to study the relationship between teacher characteristics and student achievement in Mathematics. In the first step, we use student achievement measured by scores in the 6th grade national exams to estimate teacher value-added, the measure of teacher quality. After having an estimate of the teacher quality, it was important to understand what type of characteristics can explain differences in teacher efficiency, in particular, if teachers differ in terms of quality by having an undergraduate degree obtained in a university versus a polytechnic school. It was found that teachers differ in terms of quality and that it matters for student achievement. However, these differences in quality are mostly explained by unmeasured characteristics. Taken together the observable credentials such as teacher's experience, GPA and female gender all have positive effects on teacher quality. When considering the type of degree-granting institution the effects on teacher effectiveness are different depending on the field of study.

Keywords: teacher quality, teacher credentials, economics of education, degree-granting institution

Acknowledgments: First of all, I would like to thank my advisors, *Prof. Ana Balcão Reis*, *Prof. Luís Catela Nunes*, *Prof. Mª Carmo Seabra*, for their guidance and patience across the different stages of the dissertation. I gratefully acknowledge the help provided by *Diogo Pereira* on technical issues. Furthermore, support was given by *Direção Geral de Estatísticas da Educação e Ciência*, who provided access to administrative data about schools, teachers and students in Portugal. Last but not least, I thank my *family* and *friends* for their ongoing support and encouragement throughout my years of study.

INTRODUCTION AND MOTIVATION

In Portugal, education has always been largely a state-funded service. In 2015, total public expenditure on education accounted for around 3.8% of Portuguese GDP.[1] In particular, the Government spent 2917 USD in teachers' salaries per student in public primary education (OECD, 2017).

Therefore, it is important to understand if resources are being efficiently allocated in order to promote teachers' quality. Thus, the first question we would like to answer is "Do teacher credentials reliably predict teacher quality or student achievement?". For that, data from Portuguese public schools were used to estimate teachers' effect on 6th grade students' mathematics national exam score based on a value added model and we explain which characteristics may be influencing differences in teacher quality. In this paper teacher quality is defined by how much the teacher contributes to the students' mathematics test score.

Furthermore, a Portuguese peculiarity was introduced to this analysis when answering the second research question: "Does the type of degree-granting institution matter for teacher quality?". With this, we want to understand if teacher quality is influenced by the instruction they receive in a university or a polytechnic school.

This paper is divided in seven main sections. At first, we present the importance of the topic and my motivation to write about it. In the second section, we review previous literature on the estimation of teacher impacts on students and on what type of credentials may be essential to predict teacher quality. In section 3, we explain the Portuguese educational system in respect to its structure and the teacher selection process. In section 4, we describe the data and some relevant statistics to understand the following section where we present my empirical framework used to estimate the teacher value added and important teacher credentials. In section 6, we provide a critical discussion of the results obtained. Last but not least, the paper is concluded with a brief summary of the analysis and an outlook to further research.

To sum up, this paper is intended to provide an overview of teachers' impact on students' achievement in Portugal and analyse teacher credentials that may be essential to teacher effectiveness, so as to propose critical recommendations to create an environment that fosters possible development in the educational system.

LITERATURE REVIEW

Since the publication of the Coleman Report (1966) that researchers are analysing variations in test scores gaps in relation to school resources- teacher qualification- and family socioeconomic background- parents' education level (Alexander & Morgan, 2016). More

[1] https://www.pordata.pt/Portugal/Despesas+do+Estado+em+educa%C3%A7%C3%A3o+execu%C3%A7%C3%A3o+or%C3%A7amental+em+percentagem+do+PIB-867

recently, researchers such as Todd and Wolpin (2003) recognize education as a cumulative process depending on the history of family, school inputs and innate ability.

Therefore, most of the analysis in economics of education is based on a production model, in which "schools are factories that produce learning using various school and teacher characteristics as inputs" (Glewwe et al., 2013). This idea enables researchers to analyse efficiency across educational output: what is the quantity of an educational input necessary to achieve a given level of child's output (Vignoles et al., 2009). Thus, authors such as Lazear (1999) and Checchi (2006) propose an educational production function, in which student abilities, schooling resources and cultural environment are perceived as inputs, but at the same time, student activity is also the output.

Based on this cumulative function, Todd and Wolpin (2007) investigate the determinants of students' test scores in mathematics and reading. They found that half of test score gaps can be explained by differences in mother's ability. More precisely, Carneiro et al. (2007) suggest that an additional year of mother's schooling increases the student's achievement in mathematics by 0.1 of a standard deviation.

Furthermore, home inputs, such as the regularity of home reading sessions and the engagement of the family in cultural activities, predict 25% of the black-white and 30% of the Hispanic-white test score gap (Todd & Wolpin, 2007).

For Portugal, Carneiro (2007) shows that family background determines more than half of the variation on PISA[2] results. This Portuguese result goes hand in hand with the Coleman report's statement, in which family background is the main observable characteristic explaining inequality in academic achievement.

In addition, Carneiro and Heckman (2003) admit that teachers are also an important determinant of student's success although there is lack of consensus in literature about the importance of teachers in the determination of academic achievement and future success (Rivkin et al., 2005). This uncertainty appears due to the difficulty of measuring teacher quality.

The most common method used in the Education Production Function literature to evaluate teachers' impact on students' test scores is the value-added approach due to its conceptual superiority and its provision of reliable estimates (Hanushek, 1997; Kane & Staiger, 2008). Nevertheless, critics such as Corcoran (2010) and Haertel (2013) argue that value added measures are inappropriate tools for identifying teacher quality due to the inability of a statistical model to isolate teacher's unique impact on their students' outcome.

Furthermore, Ladd (2008) identifies three challenges related to the estimation of teacher effectiveness. First of all, teachers are not randomly assigned to schools or to classrooms within schools, making it difficult to separate unmeasurable students' characteristics from teachers' effects (Clotfelter et al., 2006). Moreover, it is technically demanding to separate the effects of individual teachers from the effects of other inputs such as students' characteristics, school policies and classroom characteristics. Due to limited data, measurement errors and

[2] PISA: *Programme for International Student Assessment*

omitted variable bias are common problems, compromising the estimates and, hence, the interpretation (Rivkin et al., 2005).

Not only do education researchers disagree in terms of the approach to be used but also in terms of the importance of specific teacher factors on students' achievement.

According to Rivkin et al. (2005) having a master's degree does not have any statistically significant impact on teacher's quality. In some estimates having a graduate degree has a negative effect on students' score (Clotfelter et al., 2007).

In terms of teacher's experience, researchers seem to agree that the most important gains in teacher's quality occur in the first year of experience, but after the first year these effects vanish (Clotfelter et al., 2007; Hanushek et al., 2005; Rivkin et al., 2005; Rockoff, 2004; Wiswall, 2013). However, initial teacher performance predict quite well teaching future performance (Staiger & Kane, 2013).

Time-invariant teacher characteristics such as gender and race are widely used in literature. In a literature review by Glewwe et al. (2013), 44% of the studies found a significant negative effect of being a female teacher, while Clotfelter et al. (2007a) found that male teachers have a smaller positive effect compared to female teacher. Additionally, students benefit if the teacher is the same race as they are (Clotfelter et al., 2007a; Dee, 2005). However, it is important to emphasize that it is not possible to collect ethnic-racial data in Portugal[3], which explains the lack of Portuguese studies concerning racial characteristics.

In what concerns teacher GPA and quality of undergraduate institution, authors such as Clotfelter et al. (2007b) find that having a higher average score is associated with higher effectiveness, especially when they teach mathematics instead of reading. Furthermore, some studies rank each degree-granting institution based on a four categories' qualitative scale- "uncompetitive, competitive, very competitive, and unranked" (Clotfelter et al., 2007a). They conclude that having an undergraduate degree obtained in a very competitive institution does not increase teacher's effectiveness compared to teachers from other institutions (Clotfelter et al., 2007b).

Overall, education researchers disagree in terms of the predictive power of teacher credentials for teacher effectiveness and, hence, for students' achievement.

According to Hanushek (1997) the teacher is not the most predictive school resource for student success. Nevertheless, having a good teacher, who achieves large gains in students outcome, instead of a bad one is equivalent to attend school for one more year (Hanushek, 2002).

Based on Ladd's argument (2008) teacher credentials can be important policy drivers for improving student achievement and, hence, reduce achievement gaps.

To conclude, "teaching is effective when it enables student learning" (MET, 2013). But whether the teacher is certified or not is mostly irrelevant to determining his/her quality, since most of

[3] See "Art. 7º/1, Lei n.º 67/98 de 26 de outubro"

the observable characteristics are weakly correlated with future effectiveness (Gordon et al., 2006; Rothstein, 2015).

PORTUGUESE EDUCATIONAL SYSTEM

The Portuguese educational system is composed by kindergarten, primary, secondary and tertiary education. Kindergarten and tertiary education are not compulsory, since Portugal has 12 years of compulsory schooling. Portuguese primary education is divided in two cycles. The first one goes from the 1st to the 4th grade and the second cycle covers the 5th and 6th grades. After, the secondary schooling is also divided in two cycles. The lower secondary goes from the 7th to the 9th grade. The upper secondary education comprehends three years and is divided in four different areas, namely Sciences and Technologies, Social and Human sciences, Socio-economic sciences, and Visual Arts.

During their studies, students perform national exams in Mathematics in the 4th, 6th, 9th and 12th grade.[4]

In terms of school composition, parents can choose their children's school. However, students whose residence area is near a specific school are given priority to that same school. In primary schools, students are allocated to a classroom with a single teacher responsible for almost all subjects. In the 5th grade, students start having one teacher for each subject, meaning that each professor teaches a different subject but several classes.

Regarding teachers, the process of selection is made on a national level by the Portuguese government, which means that public schools are unable to directly hire their teachers. This centralized process is based on teachers' preferences, GPA and experience. Thus, more experienced and better qualified teachers have more chances of being placed in their first choice, since they are given priority based on teachers' status. It is important to highlight that there are two allocation processes namely the internal and external. The internal process applies to teachers classified as "professores de quadro de agrupamento" and "professores de quadro de zona pedagógica". The former are associated to a specific group of schools and, hence, they do not have to apply unless their position is in risk. The latter are obliged to apply every four years. The external process represents the opportunity for "professores contratados", teachers without a permanent link to the Ministry, to start their career as civil servants. These type of teachers need to apply every year and do not have guarantees that they will get a place.[5]

To sum up, Portugal presents a centralized model where the government is responsible for the decision making of the different procedures of the educational system.

---

4 In the secondary cycle, students perform exams in different subjects depending on their area of study.

5 See "Decreto-Lei n.º 83-A/2014 de 23 de maio" for more information about the teachers' recruitment and selection process.

PORTUGUESE DATA AND DESCRIPTIVE STATISTICS

The data used for this study is derived from administrative records managed by DGEEC[6], housed at the Portuguese Ministry of Education and Science.

In order to form the database used to predict value added estimates, I have linked different sets of records so that each student can be matched to his/her teacher in the 5th and 6th grade.

Student records include not only socioeconomic characteristic such as age, gender, nationality, education level of the parents, standardized test scores, benefiting from social support[7] subsidies, but also school and courses attended.

For each teacher, information is available on his/her undergraduate institution, year of graduation and evaluation, training details and the number of days of teaching experience.

Student and School characteristics

Crucial for this analysis is the availability of student's 6th grade exam scores reported on a scale from 0 to 100. I had to eliminate records of students until the school year 2011/12, because their exam scores were graded on a scale from 1 to 5, which limits the variability of the outcome. This implies that the teacher value added estimates are based on four cohorts: 2009/10-2011/12, 2010/11-2012/13, 2011/12-2013/14 and 2012/13-2014/15. Each cohort is composed by three school years in which the first year captures the 4th grade exam score, graded on a scale from 1 to 5, and the last year captures the 6th grade exam score, graded on a scale from 0 to 100. The first cohort, 2009/10-2011/12, includes students who did the 4th grade exam in the school year 2009/10 and the 6th grade exam in the school year 2011/12. Cohort 2010/11-2012/13 comprehends students who did the 4th grade exam in the school year 2010/11 and the 6th grade exam in the school year 2012/13. The third cohort, 2011/12-2013/14, includes students who did the 4th grade exam in the school year 2011/12 and the 6th grade exam in the school year 2013/14. The last one, 2012/13-2014/15, includes students who did the 4th grade exam in the school year 2012/13 and the 6th grade exam in the school year 2014/15.

In order to isolate teacher's effect, we only consider students who had the same teacher in the 5th and 6th grades. This represents a restriction in my estimation since it excludes students that failed in the 5th grade. Also, by restricting teachers with at least 15 student-semester observations, we minimize the measurement error associated with teacher fixed-effects estimates (Aaronson et al., 2007). However, this restriction may also bias results in specific directions since small classes could be correlated with other factors that handle success like interiority.

6 DGEEC: Direção Geral de Estatísticas da Educação e Ciência – ensures the production and statistical analysis of education and science.

7 This is measured by Serviço de Ação Social Escolar (SASE) – aims to strengthen Portuguese education system by contributing to school expenses (meals, transportation, acquisition of books) of students belonging to disadvantaged social strata.

Table 1 describes student and school level variables used to obtain the teacher value added estimates presented in the following section. The student level variables describe student's prior achievement (*Exam4)*, students' characteristics (*Female*, *Age*) and their socioeconomic background (*Pc, SS, Mhigheduc, Munemploy).*

The school level variables represent the proportion of some specific student's variable in a given school by cohort. In this case, the main characteristic analysed is the socioeconomic background of the peers (*Phigheduc*. *Punemploy, Psubsidy).* This enables me to capture the impact of peer effects on the individual student's performance.

Also, the majority of variables are dummy variables due to data specifications.

Table 1. Descriptive Statistics for the Student Data

10	Description	N	mean	sd	min	max
Student Level						
Exam6	6th grade exam score	138,038	53.91	22.38	0	100
Exam4	4th grade exam score	138,038	3.349	0.952	1	5
Female=1	if the student is female	138,038	0.505	-	0	1
Age	student's age in the 6th grade	138,038	10.11	0.432	9.002	19.70
Pc	if the student has a computer	138,038	0.735	-	0	1
SS	if the student receives social support	138,038	0.412	-	0	1
Tnonparent	if the student's tutor is neither the mother nor the father	138,038	0.039	-	0	1
Mhigheduc	if the mother has higher education	137,187	0.193	-	0	1
Munemploy	if the mother is unemployed	137,187	0.107	-	0	1
School Level						
Pfemale	percentage of female students in the school	138,038	0.503	-	0	1
Phigheduc	percentage of mothers with tertiary education in the school	138,038	0.185	-	0	0.859
Punemploy	percentage of unemployed mothers in the school	138,038	0.109	-	0	1
Psubsidy	percentage of students who receive social support in the school	138,038	0.422	-	0	1

Teacher credentials and characteristics

Table 2 compares the basic measures of teacher credentials by type of undergraduate college.

Table 2. Descriptive Statistics for the Teachers Matched in the Student Data

Variables	Description	N	Mean	sd	min	max
dummyuni 0	**Having studied in a Polytechnic School or other**					
Experience	number of days teaching	1,886	5,945	3,253	0	14,215
GPA	teacher's GPA at the end of the undergraduate degree	1,882	14.09	1.131	10	19
Field	field of study of teacher's undergraduate degree	1,886	-	-	1	8
Female=1	if the teacher is female	1,886	0.802	-	0	1
dummyuni 1	**Having studied in a University**					
Experience	number of days teaching	1,496	8,771	3,221	0	15,257
GPA	teacher's GPA at the end of the undergraduate degree	1,414	13.09	1.295	10	18
Field	field of study of teacher's undergraduate degree	1,496	-	-	1	8
Female=1	if the teacher is female	1,496	0.773	-	0	1

As we can observe, the distribution of teachers between the type of degree-granting institution is quite uniform, 56% of the mathematics teachers having graduated from a polytechnic school and 44% from a university. Also, teacher's GPA in polytechnic schools is exactly 1 point higher than the observed GPA in universities.

It is important to highlight that mathematics teachers have different types of undergraduate degree, and hence, a categorical variable was introduced to cluster degrees by field of study. The variable *field* is based on 8 groups: 1- Economics and Mathematics; 2- Arts and Design; 3- Education; 4- Engineering and Technology; 5- Health; 6- Law, History and Languages; 7- Marketing and Tourism; 8- Natural Sciences.

In order to understand the distribution of teachers by field of study and type of degree-granting institution, we present **table 3**.

Table 3. Distribution of teachers by field of study and degree-granting institution

Description	*Field*	Polytechnic School	University	Total
Economics and Mathematics	**1**	**116**	**431**	**547**
Arts and Design	2	0	3	3
Education	**3**	**1,679**	**328**	**2,007**
Engineering and Technology	**4**	**81**	**326**	**407**
Health	5	2	169	171
Law, History and Languages	6	0	3	3
Marketing and Tourism	7	1	1	2
Natural Sciences	8	7	235	242
	Total	1,886	1,496	3,382

As we can see, teachers with a degree in Arts and Design (2) or Law, History and Languages (6) only attended universities, since there is no record for polytechnic schools. Also, only two mathematics teachers have a degree in Marketing and Tourism (7), one in a polytechnic school and the other in a university. In terms of Health (5) and Natural Sciences (8), their distribution between the type of degree-granting institutions are unequal. Teachers who studied either Health or Natural Sciences are graduated from a university. The fields of study with a smoother distribution between institutions are Economics and Mathematics (1), Education (3) and Engineering and Technology (4). Therefore, the following analysis will focus on these three areas which represent 90.2% of the total number of teachers.

EMPIRICAL FRAMEWORK

Teacher Estimates

The empirical strategy proceeds in two steps. In the first step, we estimate a value-added model so that student achievement in the current year is a function of student's prior achievement and both student and school characteristics in the respective year.

Therefore, a linear regression model is expressed by:

$$A_{it} = \beta_0 + \beta_1 A_{it-2} + \beta_2 X_{it} + \beta_3 S_{it}^{g} + \sum_{m=1}^{4} \rho_m * C_{m(i,t)} + TQ_{j(i,t)} + \varepsilon_{it} \qquad (1)$$

The variables and vectors are defined as follows.

- A_{it} is achievement of student i in year t measured by the national exam score in math in the 6th grade, measured in a scale from 0 to 100.
- A_{it-2} is achievement of the ith student in the 4th grade measured by the exam score in math, measured in a scale from 1 to 5.
- X_{it} is a vector of observable student characteristics in the 6th grade like student's age, gender, and having a computer, having a non-parental tutor, and benefiting from social support. This vector also includes characteristics of the student's mother such as education and employment status.
- S_{it}^{g} is a vector of school inputs, including the proportion of students in the school that receive social support, the percentage of students whose mother has tertiary education, the proportion of students whose mother is unemployed, the percentage of female students in the school.
- C_m represents dummies for each cohort in order to capture differences in the difficulty level of exams over time, with the four cohorts being 2009/10-2011/12, 2010/11-2012/13, 2011/12-2013/14 and 2012/13-2014/15.
- β_1 , β_2 , β_3 , ρ_m are coefficients to be estimated and ε_{it} is an error term.
- $TQ_{j(i,t)}$ is teacher fixed effects (capturing each teacher j's quality).

Teacher Credentials

In the second step, we evaluate whether these value-added estimates can be explained by observational teacher characteristics.

Equation 2 provides a linear specification of teacher quality in year t:

$$TQ_j = \beta_0 + \beta_1 FEM_j + \beta_2 U_j + \beta_3 EXP_j + \beta_4 EXP_j^2 + \sum_k \beta_5^k (U_j * FS_j^k) + \beta_6 GD_j + \delta_j \quad (2)$$

Thus, teacher quality (TQ_j), measured by the teacher value-added model above, is a function of various measurable teacher characteristics, namely

- FEM_j is a dummy for being a female.
- U_j is a dummy that attributes the value 1 if the undergraduate degree is obtained in an University and 0 if it is obtained in a polytechnic school or other.[8]
- EXP_j refers to the number of days of teaching which count for seniority as an instrument for teaching experience.[9]
- FS_j^k are dummy variables, which represent each field of study.
- GD_j refers to the teacher's GPA in the undergraduate degree.

8 See Appendix 1 for a list of the degree-granting institutions

9 See "Art. 94º/2, Decreto- Lei n.º 100/99 de 31 de março"

- β_1 , β_2 , β_3 , β_4 , β_5^k, β_6 are coefficients to be estimated and δ_j is an error term.

In most of economic of education topics, there is a problem of heteroscedasticity, meaning that the variance of the random error is not constant, which would compromise the statistical inference and, thus, my results. In order to prevent this problem, I used by default robust standard errors in both models.

RESULTS AND DISCUSSION

Table 4 highlights the impact of student and school characteristics, defined in **table 1**, on students' achievement in the 6th grade exam.[10]

Table 4. Estimation Results for Teacher Value Added (the dependent variable is student's 6th grade mathematics exam score)[11]

Variables	Coefficients	Robust Standard Errors
Student Level		
Exam4	14.18***	0.049
Cohort.1113	-3.41***	0.201
Cohort.1214	5.07***	0.170
Cohort.1315	5.21***	0.205
Female	1.25***	0.084
Age	-4.36***	0.102
Subsidy	-4.68***	0.098
Pc	2.03***	0.113
Tnonparent	-2.34***	0.234
Mhighereduc	7.01***	0.115
Munemployed	-1.04***	0.142
School Level		
Pfemale	-0.974	1.170
Phighereducmother	0.989	1.314
Punemployedmother	-3.51**	1.589
Psubsidy	-2.20**	1.007
Constant	49.19***	1.335
Teacher Fixed Effects	Yes	
Observations	136,400	
F-test	8735.30	
R squared	0.5526	

Note: *** signifies coefficient is significant at the 0.01 level and ** at the 0.05 level.

It can be seen that all student level variables are significant at the 0.01 level while for the school level variables, the results are not so clear. First of all, an additional point in the student's 4th grade exam score (on a scale from 1 to 5) is linked to an increase of 14.18 points on student's 6th grade exam score (on a scale from 0 to 100). This fact confirms that education

[10] The following interpretation of the results is reported in exam score points on a scale ranging from 0 to 100.

[11] Based on the first model reported in the previous section, capturing the teacher fixed effects to obtain teacher value added estimates.

is a cumulative process since lagged inputs have a major effect on current student achievement (Todd & Wolpin, 2007).

The level of difficulty of the exams between cohorts is quite unequal, which explains the different magnitudes of student improvement in the 2 years comprehended by each cohort. It is important to highlight that the base category is cohort 1012, which include students who did the 4th grade exam in the school year 2009/10 and the 6th grade exam in the school year 2011/12. Compared to the first cohort it can be seen that students have on average less 3.41 points on the 6th grade exam score when evaluated in the school year 2012/13. Notwithstanding, students have on average more 5.07 and 5.21 points on the 6th grade exam score, when considering the cohorts 1214 and 1315, respectively.

In terms of student characteristics it can be concluded that female students on average perform better by 1.25 points than male students in the 6th grade exam score, ceteris paribus. In addition, older students have lower test scores, since the variable *age* might be a proxy for repeating the school year. Older students performing the 6th grade exam might indicate that they already failed before the current school year. Thus, one additional year in the student's age is correlated with a decrease of 4.36 points in the 6th grade exam score, ceteris paribus.

When analysing the impact of socioeconomic background in the student's current achievement, we confirm previous findings from the Coleman Report (1966), which state that disadvantaged students have lower performance on the exams. In more detail, benefiting from social support and having an unemployed mother decreases the 6th grade exam score by 4.68 points and 1.04 points, respectively. Also, a student whose tutor is neither his mother nor his father performs, on average, 2.34 points worse in the 6th grade exam compared to a student whose tutor has parental relationship, ceteris paribus. Furthermore, a student who owns a computer has on average more 2.03 points in the exam score than students without a computer, ceteris paribus. Additionally, as pointed by Carneiro (2007), having a mother with tertiary education is linked to an increase of 7 points on the exam score, ceteris paribus.

At the school level it can be seen that the percentage of female students and the percentage of mothers with higher education in the school do not influence the exam score. At the 5% level, having more unemployed mothers in the school contributes negatively by 3.51 points to the individual student's achievement. Moreover, having more social support beneficiaries in the school is inversely related to student's test score with a size of about 2.2 points.

Teachers are in fact an important asset in students' learning, since 10.73% of the variation in students' mathematics exam scores is determined by their teachers.[12]

After controlling for all the student and school level variables presented in table 1, 8.3% of the variation in students' mathematics exam scores is explained by their teachers.[13] More precisely, **graph 1** illustrates the distribution of teacher value added estimates and **table 5** details the distribution by percentile.

[12] This value is determined by the coefficient of determination, R^2, of a regression comprehending only teacher fixed effects.

[13] This value is based on the difference of the coefficient of determination, R^2, between model 1 with teacher fixed effects and model 1 without fixed effects.

Graph 1. Distribution of Standardized Teacher Value Added

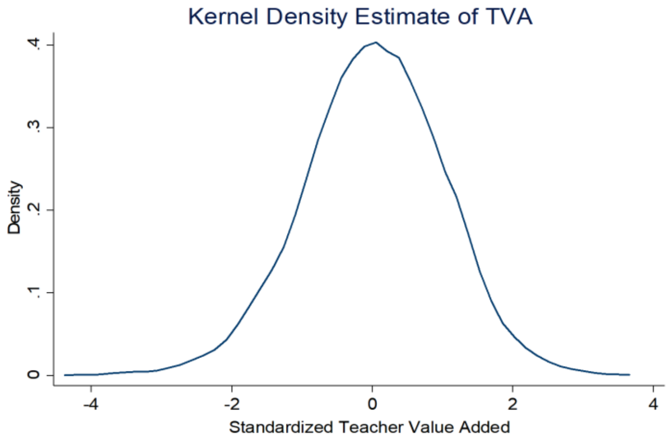


Table 5. Comparison between Standardized and Non- Standardized Teacher Value Added

Percentile Rank	*Tvastd*	*Tva*
0.01	-2.514	-18.58
0.05	-1.702	-12.26
0.10	-1.280	-9.359
0.25	-0.629	-4.858
0.50	0.0218	-0.183
0.75	0.668	4.377
0.90	1.243	8.409
0.95	1.573	10.62
0.99	2.273	16.02

It can be seen that 5% of the observations have a teacher value added estimate below -12.26, while 95% of the teachers have a positive teacher value added estimate above 10.62. This would imply that replacing the worse 5% of the teachers by the 5% best qualified teachers would have an effect of 22.88 points in the 6^{th} grade mathematics exam score, which represents 3.275 standard deviations.

Table 6 summarizes the regression results obtained for teacher characteristics and credentials. The reported regression is based on 3295 teachers. Most of the coefficients are significant at the 0.01 level and have a positive impact on teacher quality. Furthermore, the magnitude of the estimates is interpretable in terms of standard deviations of the underlying teacher value added measures since they are normalized to have standard deviation 1 and mean 0.

The findings for the teacher variables are in line with previous results in the literature (Hanushek et al., 2005), only 2.2% of the variability in teacher quality can be explained by observable characteristics such as certification and experience.

The findings correlate favourably with Clotfelter et al. (2007b) and further support the idea that teachers with more experience are more effective. Nevertheless, in my model, the benefits of teaching experience have a small magnitude of 0.00004 standard deviations per day. This means that each year of teaching experience increases teacher quality by 0.0146 standard deviations. In contrast to the results of Wiswall (2013), we conclude that the effects of teaching experience on teacher quality are linearly beneficial since the quadratic term of experience is not significant.

It would be interesting to include teacher's age in the model. However, in light of the very high collinearity between teacher's age and experience, we chose to include only *experience.*

Consistent with other studies (Clotfelter et al., 2007a; Clotfelter et al., 2007b), we find clear evidence that teachers with higher GPAs are more effective, since a one point increase in the GPA is correlated with an increase of 0.06 standard deviations on teacher value added estimates.

Table 6. Estimation Results for Teachers' Credentials (the dependent variable is the teacher value added estimate)[14]

Variables	**(2)** **Baseline:** **Polytechnic School**	**(3)** **Baseline: Economics/** **Mathematics in university**	**(4)** **Baseline: Economics/ Mathematics in polytechnic school**
Female	0.241*** (0.043)	0.231*** (0.043)	0.231*** (0.043)
GPA	0.062*** (0.014)	0.062*** (0.015)	0.062*** (0.015)
Experience	4.07e-05** (1.86e-05)	4.08e-05** (1.87e-05)	4.08e-05** (1.87e-05)
Experience2	-1.87e-09	-1.60e-09	-1.60e-09
	(1.28e-09)	(1.31e-09)	(1.31e-09)
Dummyuni	0.0285 (0.041)	-	-
ib1.Field= *Education*	-	-0.702 (0.084)	0.291*** (0.101)
ib1.Field= *Engineering/Technology*	-	-0.046 (0.072)	0.112 (0.144)
*ib0.Field*dummyuni=* *Economics/Mathematics*	-	-	0.292*** (0.104)
*ib0.Field*dummyuni=* *Education*	-	-	-0.688 (0.069)
ib0.Field(1-dummyuni)=* *Economics/Mathematics*	-	-0.292*** (0.104)	-
ib0.Field(1-dummyuni)=* *Education*	-	0.069 (0.069)	-
Constant	-1.202*** (0.214)	-1.156*** (0.213)	-1.448*** (0.231)
Observations	3,295	3,295	3,295
R-squared	0.017	0.022	0.022

Note: *** signifies coefficient is significant at the 0.01 level and ** at the 0.05 level.

Of most interest is the finding that when a mathematics teacher attended a university instead of a polytechnic school, there is no effect on quality (**Model 2**). However, when considering the interaction between different fields of study and the institution of graduation, the impact on quality is significant (**Model 3 and 4**). It is important to distinguish both models, since the interaction terms transmit almost the same information in different perspectives. **Model 3** considers the possibility of having a degree obtained in a polytechnic school and the variable *Field* represents having a degree from a university, while **Model 4** considers the interactions between the different fields of study and having graduated from a university, knowing that variable *Field* captures the opportunity of having a degree from a polytechnic School.

As stated before, the results of **Model 3** can be compared to **Model 4** and, hence, both models have a common conclusion: studying Economics or Mathematics in a polytechnic school compared to studying it in a university has a negative impact on teacher quality, with a size of about -0.292 standard deviations.

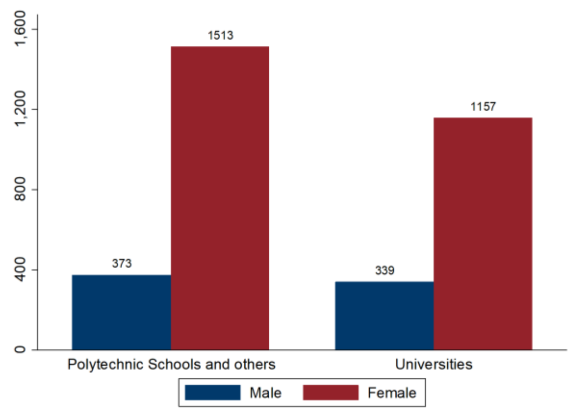
[14] These regressions are based on the second model reported in the previous section and include all eight fields of study and respective interactions. However, I chose to include only the most representative ones, as seen in section 4. Standard errors in parenthesis.

Analysing **Model 3** in detail, we might conclude that there is no gain in studying a specific field when graduating from a university. When comparing two teachers both graduated from a university, having a degree in Economics or Mathematics is as good as having a degree in Education or Engineering.

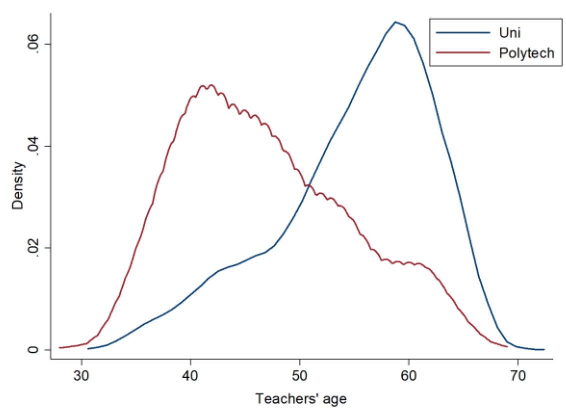
Focusing now on **Model 4**, when comparing two teachers graduated from a polytechnic school, we might state that a teacher with a degree in Education is 0.291 standard deviations more qualified than a teacher with a degree in Economics or Mathematics.

In order to examine differences in terms of teachers' characteristics based on the degree-granting institution, the following graphs should be interpreted.

Graph 2. Teachers' gender according to the type of degree-granting institution



Graph 3. Distribution of teachers' age according to the type of degree-granting institution



In **graph 2**, there is a strong presence of female individuals in the teaching staff. Nevertheless, the distribution of each gender between the type of institution is quite similar. In terms of male teachers, 48% of the male studied in a university while 52% obtained a degree from a polytechnic school. In contrast, the percentage of female teachers that studied in a polytechnic school accounts for 57%, while 43% studied in a university.

Graph 3 details the distribution of teachers' age according to the type of degree-granting institution. As it can be observed, teachers who attended a university are older than teachers who studied in polytechnic schools. This fact may be explained by the difference in the age of the institutions. In Portugal, polytechnic schools were created in the 80s with the replacement of the industrial and commercial schools by engineering and administration polytechnic schools.[15] However, universities have their origins in the 13th century, offering higher education focused on theory and research. Given the considerable difference in teachers' ages between the types of degree-granting institutions, the results from previous analysis should consequently be treated with some caution. Thus, to confirm my previous results, the sample was restricted to teachers aged 40 to 60, a range where there is a higher age overlap between

[15] See http://fap.pt/fotos/editor2/valorizacao.pdf

both groups as shown in graph 3. By imposing this restriction in model 4, the sample narrows to 2150 teachers, but the variable *Field=Education* is still significant at the 0.05 level with a positive magnitude of 0.278 standard deviations. However, the interaction *Field*dummyuni=Economics/Mathematics* turns out to be insignificant. Hence, we can state that having a degree in Economics or Mathematics obtained in a university in comparison to a polytechnic school has no effect on teacher quality. But it is still preferable for a teacher to graduate in Education than Economics or Mathematics when considering a polytechnic school.

From a policy point of view, the present findings suggest several courses of action in order to redefine teachers' accountability measures in Portugal. Nowadays, evaluation, promotion and allocation policies are based on measured characteristics such as teaching experience, GPA, age and level of education[16]. However, we saw that these credentials only explain little about teacher quality.

The goal is for redefined measures to inform Government and schools to improve teaching. This would imply that schools are able to differentiate teacher's quality, which would be an advantage to achieve different objective based on different talents. For example, if schools had the objective of reducing achievement gaps, they would have the power to match more qualified teachers to students with learning difficulties. In fact, more disadvantaged students would reach higher achievement standards and, hence, these schools would reduce their achievement gaps.

CONCLUSION

This paper investigates the correlation between teacher credentials and teacher quality. Using administrative data, I match 136,400 students with their mathematics teacher in the 5th and 6th grade in order to implement a teacher value added model. In fact, teachers have an important role in student's achievement since 10% of students' exam scores can be explained by teacher quality.

Taken together, the various student characteristics appear to have quite large effects on mathematics achievement compared to school effects. Hence, 55% of the total variation of students' mathematics exam scores around its sample mean is explained by measurable characteristics such as age, gender, prior achievement, socioeconomic background and peer effects. On the one hand, student's 4th grade exam score, student's gender, educated mothers and owning a computer have positive effects in student's exam score. On the other hand, student's age, benefiting from a social support, proxy for disadvantaged background, and having an unemployed mother have a negative impact on students' current success.

Despite the overall significance of the model, there is a specific issue that needs to be taken into account. Since we only consider students whose mathematics teacher is the same in both 5th and 6th grade, the majority of teachers captured in the sample are the most experienced

[16] In Portugal, teachers' base salary and their career progression depend on a performance appraisal based on three dimensions: scientific-pedagogical, participation in school life and educational community, and in-service training and professional development. However, since 2011, teachers' career progression is frozen, which means teachers have remained in the same pay grade.

and older, and thus the sample is not random. This is explained by the fact that experience is one of the main factors for teachers' school assignments, which means that more experienced teachers are more likely to stay at the same school for two consecutive years.

Turning now to the analysis of the determinants of teacher effectiveness, it reveals some interesting insights. First, higher GPAs indicate better qualified teachers. Second, experience has, in fact, a positive impact on teacher effectiveness. Third, teachers with a degree from a university are equally qualified as teachers with a degree from a polytechnic school, knowing that there is a difference in teacher's field of study, teacher's age and gender between institutions. Thus, a robustness check was implemented to confirm previous results.

Future studies should target unmeasurable teacher characteristics. Researchers could conduct a national survey inside each *Agrupamento de Escolas* in order to collect subjective data on teachers. It may include two different evaluation perspectives namely the teacher's and student's view. On the one hand, teachers could be asked on their satisfaction level in terms of classroom and school characteristics, on their family background and on their evaluation methods. On the other hand, similar to the MET[17] project, students could be asked to assess their teachers and classroom environment.

REFERENCES

Aaronson, D., Barrow, L., & Sander, W. (2007). Teachers and Student Achievement in the Chicago Public High Schools. *Journal of Labor Economics*, *25*(1), 95–135. https://doi.org/10.1086/508733

Alexander, K., & Morgan, S. L. (2016). The Coleman Report at Fifty: Its Legacy and Implications for Future Research on Equality of Opportunity. *The Ruįssell Sage Foundation Journal of the Social Sciences*, *2*(5), 1–16. Retrieved from http://www.rsfjournal.org/doi/full/10.7758/RSF.2016.2.5.01

Carneiro, Pedro and Heckman, J. (2003). Human Capital Policy, (2001). https://doi.org/10.3386/w9495

Carneiro, P. (2007). Equality of opportunity and educational achievement in Portugal. *Portuguese Economic Journal*, *7*(1), 17–41. https://doi.org/10.1007/s10258-007-0023-z

Carneiro, P., Meghir, C., & Parey, M. (2007). *Maternal Education, Home Environments and the Development of Children and Adolescents*. *IZA Discussion Paper Series* (Vol. forthcomin).

Checchi, D. (2006). *The Economics of Education*. Cambridge University Press.

Clotfelter, C. T., Ladd, H. F., & Vigdor, J. L. (2006). *Teacher-student matching and the assessment of teacher effectiveness*. *National Bureau of Economic Research*.

Clotfelter, C. T., Ladd, H. F., & Vigdor, J. L. (2007a). How and why do teacher credentials matter for student achievement? *National Bureau of Economic Research Working Paper Series*, *12828*(June), 1–54. https://doi.org/10.1073/pnas.0703993104

Clotfelter, C. T., Ladd, H. F., & Vigdor, J. L. (2007b). Teacher credentials and student achievement: Longitudinal analysis with student fixed effects. *Economics of Education Review*, *26*(6), 673–682. https://doi.org/10.1016/j.econedurev.2007.10.002

Coleman, J. S. (1966). *Equality of Educational Opportunity*. Retrieved from http://www.eric.ed.gov/PDFS/ED012275.pdf

Corcoran, S. P. (2010). Can teachers be evaluated by their students' test scores? Should they be? *Providence Rhode Island Annenberg Institute for School Reform at Brown University Retrieved September*, *21*, 1–46.

[17] MET: Measures of Effective Teaching Project – research partnership aimed at identifying and developing effective teaching practices

Glewwe, P. W., Hanushek, E. A., Humpage, S. D., & Ravina, R. (2013). School resources and educational outcomes in developing countries: A review of the literature from 1990 to 2010. *Education Policy in Developing Countries*, 13–64. https://doi.org/10.3386/w17554

Gordon, R., Kane, T. J., & Staiger, D. O. (2006). Identifying effective teachers: Using performance on the job. *The Brookings Institution*, (April).

Haertel, B. E. H. (2013). Reliability and validity of inferences about teachers based on student test scores (Angoff lecture). *Princeton, NJ: Educational Testing Service*.

Hanushek, E. (1997). Assesing the Effects of School resources on Student Performance: An Update. *Handbook of the Economics of Education*. https://doi.org/10.1016/B978-0-444-53444-6.00004-3

Hanushek, E. (2002). Teacher Quality. *Handbook of the Economics of Education*, *2*, 1051–1078. https://doi.org/10.1016/S1574-0692(06)02018-6

Hanushek, E. A., Kain, J. F., Brien, D. M. O., & Rivkin, S. G. (2005). *The Market For Teacher Quality*.

Kane, T. J., & Staiger, D. O. (2008). Estimating Teacher Impacts on Student Achievement: An Experimental Evaluation. *National Bureau of Economic Research*, (14607), 51. https://doi.org/10.3386/w14607

Ladd, H. F. (2008). Teacher Effects: What Do We Know? *Teacher Quality: Broadening and Deepening the …*, 1–27. Retrieved from http://www.sesp.northwestern.edu/docs/teacher-quality.pdf#page=7

Lazear, E. P. (1999). *Educational Production* (NBER WORKING PAPER SERIES).

MET. (2013). Ensuring Fair and Reliable Measures of Effective Teaching. *The Education Digest*, 59–63. https://doi.org/10.3886/ICPSR34771.v2

OECD. (2017). *Education at a Glance 2017: OECD Indicators*. Paris: OECD Publishing. https://doi.org/10.1787/eag-2017-en

Rivkin, S. G., Hanushek, E. A., & Kain, J. F. (2005). Teachers, Schools, and Academic Achievement. *Econometrica*, *73*(2), 417–458. https://doi.org/10.1111/j.1468-0262.2005.00584.x

Rockoff, J. (2004). The Impact of Individual Teachers on Student Achievement: Evidence from Panel Data. *American Economic Review*, *94*(2), 247–252. https://doi.org/10.1257/0002828041302244

Rothstein, J. (2015). Teacher quality policy when supply matters. *American Economic Review*, *105*(1), 100–130.

Staiger, D. O., & Kane, T. J. (2013). Making Decisions with Imprecise Performance Measures: The Relationship Between Annual Student Achievement Gains and a Teacher's Career Value Added. *Designing Teacher Evaluation Systems: New Guidance from the Measures of Effective Teaching Project*, 144–169. Retrieved from http://www.metproject.org/downloads/Designing Teacher Evaluation Systems_freePDF.pdf

Todd, P. E., & Wolpin, K. I. (2003). On the specification and estimation of the production function for cognitive achievement. *Economic Journal*, *113*(485), 3–33. https://doi.org/10.1111/1468-0297.00097

Todd, P. E., & Wolpin, K. I. (2007). The Production of Cognitive Achievement in Children: Home, School, and Racial Test Score Gaps. *Journal of Human Capital*, *1*(1), 91–136. https://doi.org/10.1086/526401

Vignoles, A., Dearden, L., & Machin, S. (2009). Economics of education research: a review and future prospects, *35*(5), 617–632. https://doi.org/10.1080/03054980903216333

Wiswall, M. (2013). The dynamics of teacher quality. *Journal of Public Economics*, *100*, 61–78. https://doi.org/10.1016/j.jpubeco.2013.01.006