Teachers' satisfaction as indicator of education system' performance

Marcenaro-Gutierrez, O. D.[1], Luque, M.[2 *], and Lopez-Agudo, L. A.[1]

[1] *Department of Applied Economics (Statistics and Econometrics)*

[2] *Department of Applied Economics (Mathematics)*

Universidad de Malaga, C/ Ejido, 6, 29071, Malaga, Spain

Abstract

We investigate the potential trade-off between some teacher characteristics, particularly teachers' satisfaction, and different measures of pupils' performance, in order to optimize the outputs of the Spanish education system. Our contribution to the existing literature is twofold: on the one hand, we provide estimates on the balance between teachers' effectiveness and 4th grade students' performance in Spain, by using recent survey data (TIMSS, 2011); on the other hand we implement a novel methodology which allows optimizing simultaneously a set of indicators on the outputs of the educational system. These analyses provide empirical evidence of the importance of investing in teacher satisfaction as a motivation mechanism for improving national educational achievement.

Key words: teachers' satisfaction, pupil performance, trade-off, TIMSS 2011.

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*Corresponding author e-mail: odmarcenaro@uma.es; Tel.: +34 95 213 7003.

E-mail addresses: mluque@uma.es; luisalej90@gmail.com.

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1. Introduction

Education is a key factor to explain economic growth (Barro 2001). Students' performance at early stages[1], particularly primary education, is clearly correlated with the national development of human capital accumulation and any factor affecting the quality of human capital production will directly affect future economic growth.

That is the main reason to explain the growing number of empirical studies that have investigated the factors influencing students' performance. The main emphasis of the previous literature on education production functions is on the relationship between a set of "quantitative" inputs and pupil outcomes, the latter mainly measured by some standardised scores. This means that other significant dimensions of the output have received less attention, despite the potential implications in terms of educational policies. For example, most of these papers pay little, if any, attention to the role of teachers' quality in the framework of the education production function, which is an important limitation. Nevertheless this seems to be shifting to some extent, as the satisfaction of the teachers, and in many other occupations, is a matter of increasing concern from a policy perspective in most countries, although not specifically for the education policy.

In fact, it is often argued that, as reported by Barber and Mourshed (2007 p. 4) "the quality of an education system cannot exceed the quality of its teachers" and the esteem that teachers have in different societies varies widely, which means that teacher quality and its relationship to pupil performance is at the very heart of the debate about educational policy (Dolton & Marcenaro 2011). In other words, a good education system requires good teachers and for this we need teachers not only with effective teaching skills, but also teachers with high levels of satisfaction. In this sense, we need to draw specific attention to the teachers and examine the extent to which variations in the way teachers feel in different schools may be a good proxy for the educational outcomes of primary schools pupils.

Turning this logic around we suggest that the quality of teachers is likely to be higher if they are satisfied with their job and that teacher satisfaction at present is the main mechanism to attract and retain –in the long run– the best graduates into the education system. As the potential supply of teachers rises because of the higher satisfaction, entry into teaching will become more competitive. This, in turn, will mean that the average ability of those entering the job will rise. Consequently, we must determine not only the factors helping to achieve higher students' performance, but also higher levels of teacher satisfaction. In other words, we have to find a balance among those "outcomes" to "guarantee" the improvement of the education system.

[1] Pupils' test scores should be considered a good proxy of individual's ability (De Coulon, Marcenaro and Vignoles 2011).

Thus, our standpoint is that teacher satisfaction is an indicator of how good is the education system and, consequently, we need to account for this when evaluating the factors behind the improvement of the education system. So, our thesis is that policy makers should define increasing levels of teacher's satisfaction as an educational target at the same time that they seek to achieve higher levels of pupils' performance and lower proportions of students below the basic achievement level. Ideally, to define the best educational policy practices, we would like to know the extent to which the different proposed targets are achievable simultaneously or, by contrast, there are important trade-offs. To achieve this we need to go a step further, by combining traditional econometric estimates with multiobjective programming. The reason to choose the latter methodology is the existence of "bad outputs", which should be minimized, and "good outputs", which should be maximized throughout the teaching-learning process, as well as more qualitative outputs, such as teachers' satisfaction with their work. We intend to achieve these maximizing-minimizing objectives simultaneously. Thus, we seek to establish whether microdata supports the existence of a trade-off between an indicator of teachers' satisfaction and two different measures of students performance (i.e. average students performance and percentage of students achieving basic standards of learning). In order to measure the satisfaction of teachers, the teachers' career satisfaction index provided by the program on Trends in International Mathematics and Science Study (TIMSS) 2011 is going to be used. This index is based on 4th grade teachers' reports of their agreement with the following statements about their career's satisfaction: "I am content with my profession as a teacher"; "I am satisfied with being a teacher at this school"; "I had more enthusiasm when I began teaching than I have now"; "I do important work as a teacher"; "I plan to continue as a teacher for as long as I can"; and "I am frustrated as a teacher".

By using 4th grade students we ensure that the students enrolled in each class are taught by the teacher under scrutiny. The average age at time of Testing was 9.8 years.

The next section describes briefly the previous literature on this topic and, particularly, those papers focused on teachers' satisfaction. Section III describes our data. The methodological approach adopted is shown in Section IV, before we present the main results of the empirical approach in Section IV. Section V concludes discussing some policy implications of our results.

2. Literature Review

Despite the potential importance of the link between good teachers and effective student learning, to the best of our knowledge, the literature on this is scarce, particularly in countries like Spain, mainly because of the difficulty to get access to good observational data to build a reliable indicator measuring "how good a teacher is". As a consequence, the Spanish education policy does not seem well orientated in that, so it is not sensitive enough to substantiate the link between quality and effectiveness of teachers. In what follows we briefly review the literature on this topic to illuminate this less explored strand of the ongoing educational debate, paying special attention to papers exploring teachers' satisfaction as a proxy for teachers' quality. In this vein, Kumar (2014) found a positive correlation between teaching effectiveness at primary education level (the one we focus on) and job satisfaction. This means that teachers who were highly satisfied with their jobs were the most effective in teaching, while those who had low level of job satisfaction were the least effective ones in teaching, from what the author inferred the existence of a positive correlation between job satisfaction and teaching effectiveness. Other interesting result of this study was the gender issue, as female teachers were more satisfied towards their job and lot more effective in teaching than their male counterparts. This fact could be of relevance also in our model, so we have controlled for teacher gender in our estimates.

Michaelowa (2002) studied primary teachers in Africa and found that there is a positive effect of teachers' job satisfaction on the quality of the education they are providing. However, they remarked that there are many cases when this relationship does not happen, particularly with the implementation of measures based on more control to increase students' achievement –such as defining harder working conditions for teachers–, what reduces teachers' satisfaction. Other variables, e.g. classroom equipment, benefited teacher performance and satisfaction. They also found that, in order to increase both teachers' satisfaction and students' achievement, teachers should not have qualifications higher than a Baccalaureate degree, because teachers with higher qualifications may face more difficulties when teaching in primary schools due to their higher aspirations.

But this relation between teacher effectiveness and satisfaction is not limited to primary school, and has been under evaluation at the more often at the secondary school teachers level. Tek (2014) highlighted that those secondary schools which presented higher satisfied teachers performed better in mathematics. School leadership also played an important role in the interaction of satisfaction and achievement, to the extent that leaders can create a proper working climate where teachers can feel safe to try out new teaching methods. Similarly, Akiri (2014) analyzed the relationship between students' achievement and teachers' career satisfaction in secondary school; he found that female teachers were more satisfied than males and that more qualified and experienced teachers were less satisfied, due to their feeling that are not being rewarded enough. In addition, they declare that better salaries and working conditions might increase their satisfaction, what will help to retain highly qualified teachers.

In the field of self-assessment and motivation, Caprara et al. (2006) examined the contribution of teacher's self-efficacy beliefs and satisfaction at the school level, finding that a strong sense of efficacy exhibits high levels of planning and organization. Likewise, Allinder (1994) highlighted this and also that those teachers with these characteristics were open to new ideas and were more willing to experiment with new methods, in order to better meet the needs of their students (Cousins and Walker 1995). They also exhibit enthusiasm for teaching (Allinder 1994), what can have a positive influence on students' achievements and their own sense of efficacy (Tschannen-Moran and Woolfolk 2001).

In this vein, Klassen and Chiu (2010) found that teachers' years of experience showed nonlinear relationships with self-efficacy factors, increasing from the first steps of their careers to the middle, and then falling afterwards. They also established that female teachers had greater classroom and workload stress from student behaviours, in addition to a lower classroom management self-efficacy. Besides, teachers with higher workload stress had greater classroom management self-efficacy, whereas teachers with greater classroom stress had lower self-efficacy and lower job satisfaction. On the other hand, teachers with greater classroom management self-efficacy or instructional strategies self-efficacy had greater job satisfaction.

Also regarding with the effect of teachers' gender, Broughman (1997) –as in Kumar (1994)- concluded that female teachers tend to be more satisfied than male school teachers, while teachers with less experience tend to be more satisfied than teachers with more experience. After controlling for other factors, the multivariate analysis indicated that salary did contribute to teacher satisfaction in a positive way. But, although it was statistically significant, salary factors did not contributed so much to the prediction of teachers' satisfaction, what suggests that the satisfaction of teaching as a career has a higher effect on teacher satisfaction than lucrative based satisfaction. In the case of the Spanish education system, public school teachers are paid – according to their experience– very similarly, thus teachers' salary is not expected to account for variations in teacher effectiveness.

The decomposition of satisfaction determinants was also studied by Dinham and Scott (1998), who developed a model of teacher and school executive satisfaction derived by using factor analysis. These factors were divided into three domains: school level factors (school leadership, decision making; climate; school infrastructure; and school reputation); core business of teaching factors (professional self-growth; and student achievement); and system level factors (status and image of teachers; workload and impact of change; and merit promotion). They concluded that the core business aspects were the ones of which teachers were more satisfied, while they were less satisfied with system level factors.

Predictors of teacher job satisfaction were investigated by Kim and Loadman (1994), which could provide valuable information about teacher satisfaction and expectations. Their analysis produced a model in which seven variables were statistically significant: salary, opportunities for advancement, working conditions, professional challenge, interactions with colleagues, professional autonomy and interaction with students. In the case of salary and opportunities for advancement, they were generally perceived as extrinsic sources of satisfaction, in the way that they are rewards often controlled by others. The other cases were intrinsic satisfiers, like professional challenge, working conditions, professional autonomy, interaction with colleagues and interaction with students, because they are rewarding in themselves. They found that all of these previously mentioned variables had a positive effect on teachers' satisfaction.

Regarding with the alternative ways of measuring students' performance employed in this study, the percentage of students who could not achieve a basic level was used by other studies as Giménez et al. (2014), who measure performance change in the educational systems of 28 countries participating in the TIMSS 2007 and 2011 for eighth grade basic education students. They minimized that percentage at the same time as they maximized students' achievement in mathematics in each country. One interesting result was that an orientation to good output (higher mean scores), or to both of them, reduced the achievement of the education systems, while an orientation to the bad output (proportion of students below the basic level) increased the achievement of a country, and also the dispersion was lower. This good and bad outputs approach, which is going to be employed in the present study, has been commonly used in the field of efficiency in energy production, with the aim of studying the efficiency of firms' productive processes and their environmental repercussions (Färe et al., 2005; Watanabe and Tanaka, 2007; Sueyoshi and Goto, 2011). However, to the best of our knowledge, it has received very little attention in the field of Economics of Education.

3. Data

The information analyzed in this paper comes largely from the latest release of TIMSS 2011. This program sampled students in a two-stage clustered sampling design, in which schools were selected in the first stage, and two math classes were randomly sampled within each of these schools in the second stage[2]. The main sample was designed to be nationally representative of pupils in the target age group and so the sampling criteria ("stratifiers") for each country are designed to address key characteristics of the nation's school system. The Spanish sample contains 151 schools (102 public and 49 semi-private), 200 teachers and 4183 students; each student was univocally matched to one teacher. The use of the satisfaction index reduces our sample to 190

[2] Within each sampled class, at least 85 per cent of pupils were expected to take part.

teachers, because there were some 10 teachers who did not answer those questions related to the composition of this index. Within each sampled class, in principle all students participated in the assessment. In practice, however, the number of students included in the sample will be smaller than the actual class size because of students who did not participated (Williams et al. 2009). To account for this complex sampling design, sampling weights were applied and a jackknife resampling technique was employed to calculate standard errors correctly in statistical analysis.

As above mentioned, teachers' career satisfaction index provided by TIMSS 2011 is based on 4th grade teacher' reports of the extent of their agreement with some statements about their satisfaction with their career: "I am content with my profession as a teacher"; "I am satisfied with being a teacher at this school"; "I had more enthusiasm when I began teaching than I have now"; "I do important work as a teacher"; "I plan to continue as a teacher for as long as I can"; and "I am frustrated as a teacher". Teachers' responses to those questions were averaged on a 4-point scale as follows: Agree a lot = 1; Agree a little = 2; Disagree a little = 3; and Disagree a lot = 4. After reverse-scoring relevant items, TIMSS 2011 assigned students whose teacher's average was 3 or greater to the Low level of the index, students with a teacher averaging between 2 and less than 3 were at the Medium level, and students with a teacher averaging less than 2 were assigned to the High level of the index. Students were scored according to their teachers' degree of agreement with the six statements on the scale. For example, students with "satisfied teachers" had a score of at least 10.0, due to their teachers "agreeing a lot" with three out of the six statements and "agreeing a little" with the rest, on average. Students with "less than satisfied teachers" had a score lower than 6.5, which corresponds to their teachers "disagreeing a little" with half of the six statements and "agreeing a little" with the rest, on average. All other students had "somewhat satisfied teachers".

We seek to establish the potential existence of a trade-off between that indicator of teachers' satisfaction and two different measures of students' performance: average students' performance and the percentage of students who do not achieve basic standards of learning. Thus the measures of students' performance are, on the one hand, the average scores in standardised tests in maths[3] by teacher and, on the other hand, the proportion of students by teacher not achieving basic standards of learning, i.e. with scores below 400 points[4]. Basically the students below basic level are those who get scores below the average of the whole set of

[3] For the sake of brevity and taking into account the high correlation between maths and sciences scores, we have focused on maths.
[4] This is the international standard definition, which defines the following achievement levels: advanced level (>625 points); high level (>550 & <=625); intermediate level (>475 & <=550); basic level (>400 & <=475) and below basic level (<400).

countries participating in TIMSS 2011 minus one standard deviation. This is related to international standards so is less related to a within country standard.

Full descriptive statistics for the sample under scrutiny are provided in Table A2 (Appendix A), reporting the mean and standard deviation for the exam scores in mathematics, for the proportion of pupils below the basic level as well as the teachers' satisfaction index for the whole set of variables (in Table A1 the labelling of the variables under scrutiny has been reported) being evaluated. In brief, Table A2 shows that, in classrooms where the proportion of students with 100 of more books at home is above 42.5%, the achievement both in terms of average scores and proportion of students above the basic level is much better, and also the teachers' satisfaction index gets closer to the top. Similarly, when the proportion of students who assert that their teacher is easy to understand is at the top, all the outcomes move towards increasing levels of achievement –by the students– and satisfaction –for the teachers–. Particularly relevant for the latter outcome is –also– the proportion of classroom students who are congratulated by the teacher for their work in maths, however it seems not clearly correlated with the proportion below the basic performance level, which means that some trade-offs must be going on. Interestingly enough, these bivariate descriptive statistics allow to state that female teachers are more satisfied towards their job than their male counterparts, in line with the results reported by some of the authors highlighted in the literature review.

4. Econometric analysis

As above mentioned, we should not consider the success of an education system only by maximizing the average performance of the students, but also minimizing the percentage of students not achieving basic –international– standards of learning and, additionally, –from the teachers' side– maximising teachers' satisfaction with their work.

Simple linear regression models have been estimated, in which students' average performance by teacher in mathematics, the proportion of pupils below the basic performance level and teachers' satisfaction index are regressed on the set of explanatory variables reported above. Students' performance is a continuous standardised variable, the proportion of pupils below the basic performance level is also continuous, but censored variable, and teachers' satisfaction index is also continuous.

The coefficients obtained from estimating the linear regression model are used to build the three objective functions that we wish to optimize simultaneously (two of them to maximize and the other one to minimize), thus having a multiobjective programming problem.

As previously outlined, we can proxy the output of the educational process through different categories of students' performance. The level for each of these performance targets results from the combination of a set of individual and contextual features, unobservable factors and a random disturbance (ε). The idea behind the OLS estimator is to minimize the latter term in order to get rid of the so-called "statistical noise" as much as possible. If teachers' order number is indexed as 'i', and the three outputs considered (i.e. average students' performance for each teacher, proportion of students below basic level and teachers' satisfaction level) are indexed as 'j', this model can be represented by the following set of equations[5]:

$$P_j(i) = \hat{\alpha}^j + \hat{\beta}_1^j d1(i) + \hat{\beta}_2^j d2(i) + \cdots + \hat{\beta}_{19}^j saf(i) + \varepsilon_j(i) \qquad (1)$$

$$i = 1, \ldots, n \ (number\ of\ observations, 190\ teachers);$$

$$j = 1,2,3\ (1 = average\ scores\ in\ maths; \quad 2 = proportion\ below\ basic\ level;$$

$$3 = teachers' satisfaction).$$

where $P_j(i)$ is a measure of the output 'j' for tteacher 'i', and $d1(i), d2(i), \ldots, saf(i)$, a set of explanatory variables; $\varepsilon_j(i)$ is a random disturbance; $\hat{\beta}^j = \left(\hat{\beta}_1^j, \hat{\beta}_2^j, \ldots, \hat{\beta}_{19}^j\right)^T$ a vector of slope coefficients and $\hat{\alpha}^j$ a fixed but unknown population intercept. The size of the sample is represented by the integer value 'n'. Therefore, we are assuming that each of the three outputs is affected by random factors which are inherently unobservable and distributed normally. This parsimonious model is characterized by the parametric nature of its specification; the estimated parameters represent average educational production functions, i.e. the average combination of a set of educational inputs measured at teacher aggregated level transformed to obtain an average output level.

In order to get the best fitted model, many TIMSS 2011 variables for Spain were tested at teachers' level. These variables were related to the level of training of the teachers; teachers' frequency of meeting with students' parents; mathematics teaching time per week; whether the use of calculators or computers was allowed or not during mathematic classes; frequency of homework assignment; attendance to professional development courses; the proportion of students –taught by the teacher– who did like school; the proportion of students –taught by the teacher– who enjoyed mathematics; the proportion of students –taught by the teacher– whose parents checked their homework every day; other methods of teacher evaluation as observations by the principal (or senior staff), by inspectors or other persons external to the school and, last, teacher peer review and school problems as teachers arriving late at school or not attending.

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[5] This technique for modelling the educational process of exam performance is the educational production function.

TIMSS only differentiates between private and public schools, so it does not distinguish between private and semi-private schools. The number of private schools for Spain[6] is 49 and public schools are 102, but this variable was not significant when used in the model, so this distinction was not employed in the rest of the analysis. An additional issue with regard to the regressors is that the variable which measures the level of safety which teachers feel in their school has been grouped into "agree a lot" or not. This is due to the lack of observations in the category "disagree a lot" and the presence of only 3% of observations in the category "disagree a little", what made us grouping these two mentioned categories with "agree a little". This let us differentiate among those who are sure about their feeling of high safety and those who are not (teachers who selected another option).

Table B1 (Appendix B) shows the estimated coefficients of the key variables of interest; it also reports the standard deviations and the significance levels for each coefficient. The coefficients reported were normalised, although they are going to be interpreted relying on their original values in order to provide more intuitive explanations.

A missing flag variable was introduced with the aim of controlling the proportion of students –by teacher– who did not answer the corresponding question, in the case of the students' questionnaire. For the teachers' and school questionnaire this missing flag represents which of these units did not answer the question, respectively[7].

Focusing on the results, we find that teachers who have students with diglossia have lower average scores, being this negative effect increased as the proportion of students with diglossia grows. When the proportion is higher than 12%, the percentage of students under the basic level is increased by 4.2%. This result was highlighted by Carabaña (2014), who found that diglossia decreased students' achievement and, thus, it increased the probability of grade repetition due, to some extent, to the correlation between diglossia and immigration status of the student.

The effect on students' math achievement of the proportion of students with 100 or more books in their home is particularly positive at the upper end of the percentage distribution. It also reduces the proportion of students under the basic level (in 8.3% for a teacher with 27.5% to 42.5% of his/her students with 100 or more books at home and in 7.5% when this percentage is higher than 42.5%). This variable was used as a proxy of cultural level by authors as Calero and Escardibul (2014) and Carabaña (2014), which was said to increase

[6] In the final sample it is 49 and 95, respectively.
[7] These missing flag variables were not reported in Table B1 (Appendix B) for space reasons, but they will be provided upon request from the authors.

students' performance. The effect of the missing flag variable reflects that the proportion of students who did not answer the question would reduce the average performance of teacher's students in 197 points and it would increase the proportion of students under the basic level in 74.7%. Thus we have to consider the estimated coefficient as being downward biased.

Same pattern, as the variable of books at home, can be found in the case of the proportion of students who declare that their teacher is easy to understand. Besides, it increases teachers' satisfaction by 0.898 index points, in the case that the percentage of students declaring this fact is located between 89% and 95.5%. Also affecting teachers' satisfaction, we found that those teachers who congratulate more than 76.5% of their students are 1.28 index points more satisfied than in those in classrooms where the proportion was lower.

The students from schools whose directors agree "a lot" that there is a great lack of mathematics' teachers in their school get, on average, 25.85 points less in mathematics, and those who only agree have less satisfied teachers (approximately 1 index point).

The evaluation method based on students' achievement has a positive effect on students' average scores and it also reduces the ratio of students who perform under the basic level by 6.3%. The missing flag for this variable shows that this evaluation method could be in detriment of teachers' satisfaction, maybe because of the pressure or uncertainty they could be facing, or confusion about the control of this evaluation method, which does not provide information for the improvement of teachers capabilities (Peterson and Kauchak 1982).

Teachers' years of experience show an inverted U shape, which denotes the existence of concavity. The more the years of experience of the teacher, the higher average performance of the students. Despite this positive effect, we found that it is marginally reduced when the number of years of experience increases, concretely, after 23.4 of years of experience. This variable was also analysed by authors such as Goldhaber and Brewer (1997), who highlighted the fact that students were benefited by the higher years of experience of their teachers. However –more recently– Decker et al. (2004) have established that having no previous experience would be more beneficial and many other researchers suggest that teachers improve more at the beginning of their careers (Becker 1993; Rockoff 2004), although beyond their first few years, teachers may continue to improve their practices (Huberman 1992). This pattern reflects theories which state that less experienced teachers are often trying to survive in the classroom until they learn the curriculum, develop key classroom management skills and increase their instructional abilities (Johnson and Birkeland 2003). However, there is less agreement about the nature of returns to experience after these early years. Nevertheless, other research papers suggest that teachers who enjoy strong job protections may stop improving once they become established in their schools (Hansen 2009).

An additional noteworthy result is that gender of the teacher does not seem to influence on any of the outcomes under evaluation. Thus, the potential correlation between both variables vanishes when condition on other variables.

Finally, the effect of a very high feeling of safety in the school by the teacher raises the average scores by 15.75 points and increases teachers' satisfaction, on average, by 1.39 index points. This feeling of safety was studied by Gregory et al. (2012), who found that this variable had a positive effect on teachers' satisfaction and performance.

5. Specification and resolution of a Multiobjective Programming Model

5.1. Concepts and notation in Multiobjective Programming

In order to solve the multiobjective problem proposed in this study it is necessary to establish the basic definitions and notations. Considering the following general multiobjective problem:

$$\begin{aligned} &\max f(\mathbf{x}) = \big(f_1(\mathbf{x}), \dots, f_k(\mathbf{x})\big) \\ &s.t.: \qquad \mathbf{x} \in X \end{aligned} \tag{2}$$

involving k (≥ 2) conflicting objective functions $f_i: X \to \mathbb{R}$, which must be maximized simultaneously and where $\boldsymbol{x} = (x_1, \dots, x_n)^T$ are the *decision variables*. The $\boldsymbol{x}$ vector belongs to the feasible region $X \subset \mathbb{R}^n$, which is a nonempty compact set. The image of $X \subset \mathbb{R}^n$, $Z = f(X)$, is called feasible objective region, and $\boldsymbol{z} = f(\boldsymbol{x})$ is an *objective vector*, where $\boldsymbol{z} \in Z$ if $\boldsymbol{x} \in X$.

It is common that multiobjective optimization lacks a feasible solution to simultaneously maximize all objective functions. Because of that, the efficiency concept of optimality appears where none of the components can be improved without deteriorating at least one of the others: a decision vector $\boldsymbol{x}' \in X$ can be defined as efficient or Pareto optimal solution of the problem (2) if there does not exist another $\boldsymbol{x} \in X$ such that $f_i(\boldsymbol{x'}) \leq f_i(\boldsymbol{x})$ for all $i = 1, \dots, k$, with at least one strict inequality. When this happens, $\boldsymbol{z'} = f(\boldsymbol{x'})$ is called nondominated objective vector. The efficient set is denoted by E and $f(E)$ is the nondominated objective set. A decision vector $\boldsymbol{x'} \in X$ is called weakly efficient or weakly Pareto optimal if there does not exist another $\boldsymbol{x} \in X$ such as $f_i(\boldsymbol{x}') < f_i(\boldsymbol{x})$ for all $i = 1, \dots, k$. The corresponding objective vector is called weakly nondominated objective vector. In addition, it is necessary to highlight that the set of efficient solutions is a subset of the weakly efficient solutions.

Furthermore, since the set of nondominated objective vectors contains more than one vector, it is useful to know the bounds for the objective vectors in the nondominated objective set. On the one hand, lower bounds are set by the nadir vector $\boldsymbol{z}^{nad} = \left(z_1^{nad}, \dots, z_k^{nad}\right)$, where $z_i^{nad} = min_{x \in E}\, f_i(\boldsymbol{x})$ for all $i = 1, \dots, k$, while upper bounds are given by the ideal values $\boldsymbol{z}^* = (z_1^*, \dots, z_k^*)$, where $z_i^* = max_{x \in E}\, f_i(\boldsymbol{x}) = max_{x \in X}\, f_i(\boldsymbol{x})$ for all $i = 1, \dots, k$. The nadir vector is not easy to obtain and when estimated from the pay-off table the values achieved are not necessarily good approximations (for details, see e.g. Ehrgott and Tenfelde-Podehl 2003; or Miettinen 1999). Recently, Deb and Miettinen (2010) and Deb et al. (2010) proposed many approaches for a more reliable nadir vector generation. Both the ideal vector and the nadir vector are used frequently to normalize the objective functions since the range normalization is the most used one. In the case of this study, this normalisation has been previously performed.

Since all efficient solutions can be considered equivalent from the mathematical point of view, it is necessary to incorporate some preferential information into the model. Preferences about efficient solutions are commonly expressed by the so-called reference point $\boldsymbol{q} = (q_1, \dots, q_k)^T$, which consists of reference values for the objective functions. Given these values and a vector of weights $\boldsymbol{\mu} = (\mu_1, \dots, \mu_k)^T$, the so-called achievement scalarizing function is built and minimized over the feasible set. Wierzbicki (1980) proposed one of the most commonly used achievement scalarizing functions:

$$s(\mathbf{q}, f(\mathbf{x}), \boldsymbol{\mu}) = \max_{i=1,\dots,k}\{\mu_i(q_i - f_i(\mathbf{x}))\} + \rho \sum_{i=1}^{k} \mu_i (q_i - f_i(\mathbf{x})) \qquad (3)$$

which must be minimized in the feasible region:

$$\begin{aligned} &\min\ s(\mathbf{q}, f(\mathbf{x}), \boldsymbol{\mu}) \\ &s.t.: \qquad \mathbf{x} \in X \end{aligned} \qquad (4)$$

with $\mu_i > 0$ for all $i = 1, \dots, k$ and where $\rho > 0$ is a so-called augmentation coefficient, which must be a small value, and which assures the efficiency of the solutions generated. Only the weak efficiency of the solution is assured when the second term is not used. The vector $\mu = (\mu_1, \dots, \mu_k)^T$ with $\mu_i > 0$ for all $i = 1, \dots, k$ is formed by the weights assigned to reach the reference values and can have different meanings (see Luque et al. 2009).

Nondominated solutions are produced by problem (4) and it is demonstrated that any Pareto optimal solution can be found by solving (4) using the ideal objective vector as reference point (or any objective vector that dominates it, as an utopian vector), and varying the weight vector in the whole weight vector space (Kaliszewski 1994). It is also demonstrated that any Pareto optimal solution can be found by solving (4) when fixing the weight vector and varying the reference point (Miettinen 1999).

A possible inconvenience of the achievement scalarizing function (3) to be solved in (4) is that it is generally non-differentiable, even if the objective functions of the problem (2) are all differentiable. However, this difficulty can be overcome by considering the following equivalent formulation to the problem (4):

$$
\begin{array}{ll}
\min & \alpha + \rho \sum_{i=1}^{k} \mu_i \left(q_i - f_i(\mathbf{x})\right) \\
s.t.: & \mu_i\left(q_i - f_i(\mathbf{x})\right) \le \alpha \qquad i = 1, \dots, k \\
 & \mathbf{x} \in X
\end{array}
\tag{5}
$$

Considering the differentiable formulation (5), the resulting single objective optimisation problem will be solved using the optimization toolbox function for Matlab 2012[8]. This kind of problem has already been treated in the scientific literature. For example, a decision support system using interactive reference point approaches was proposed by Alves and Climaco (2004) to solve multiobjective integer and mixed-integer programming problems.

5.2. Data characteristics

Although not all the variables considered in the econometric study described above are controllable by a decision maker, we will consider all of them as decision variables for the multiobjective model.

5.3. Constraints

We now define the set of constraints of the model. There is a set of technical constraints which ensure that certain binary variables do not take the value "1" simultaneously. Let us recall that the reference value of each group (which is assumed to be equal to 1 if the rest are equal to 0) is not considered a variable, which is the reason why the constraints reported in Table 5.1 are inequalities, except for the constraint (C7), which represents a quadratic constraint.

Table 5.1

Set of technical constraints for binary variables

d1+d2 ≤ 1	(C1)	*evach* ≤ 1	(C6)
b1+b2+b3 ≤ 1	(C2)	*yexp-yexp2=0*	(C7)
und1+und2+und3 ≤ 1	(C3)	*male* ≤ 1	(C8)
c1+c2+c3 ≤ 1	(C4)	*saf*≤ 1	(C9)
spec1+spec2+spec3 ≤ 1	(C5)		

Source: Compiled by authors.

The restriction (C7) is the result of an inverted U shape relationship in the behaviour of teachers' years of experience, as it was previously mentioned in the econometric analysis (section 4). Thus, the problem becomes nonlinear and then we have a mixed-integer nonlinear multiobjective optimization problem.

In addition, other constraints have been derived from clear dependencies observed in the regression analysis. This means that we have chosen those pairs of variables whose dependencies were stronger according

[8] Specifically, a function developed for Matlab Optimization Toolbox by Jonathan Currie was used (OPTI Toolbox), designed to solve single objective mixed-integer nonlinear programming problems.

to this analysis, and thus it is not realistic to give them independent values. One of them is the variable '*yexp*'; all the dependencies between this variable and the rest included in our model have been checked, from where two-sided constraints have been build, using the 99% confidence intervals; these bounds for α and β are presented in Table 5.2. In this table the first row corresponds to the lower and upper bound of β and the second row corresponds to α. In order to make this procedure more understandable, an example using the proportion of students taught by the teacher with 100 or more books at home, when this proportion is between 27.5% and 42.5%, is provided:

Dependency between '*yexp*' and '*b2*'. The linear regression is given by:

$$yexp = a \cdot b2 + b$$

where the confidence intervals of the coefficients are (at 99%):

$$a \in [a^l, a^u] = [-0.948, 8.762] \text{ and } b \in [b^l, b^u] = [17.075, 21.747]$$

which implies:

$$a^l \cdot b2 + b^l \leq yexp \leq a^u \cdot b2 + b^u$$

because of that, two new constraints are incorporated into the model:

$$yexp - (8.762 \cdot b2 + 21.747) \leq 0 \quad \text{(C10)}$$

$$yexp - (-0.948 \cdot b2 + 17.075) \geq 0 \quad \text{(C11)}$$

The same procedure will be applied in order to get the (C12) and (C13) constraints.

Table 5.2

Technical constrains for dependency between '*yexp*' and the rest of variables.

Variables	Lower bound		Upper bound	
b2	-0.948	(C11)	8.762	(C10)
	17.075	(C11)	21.747	(C10)
b3	-0.926	(C13)	8.567	(C12)
	17.010	(C13)	21.731	(C12)

Source: Authors' own calculations.

5.4. Objective functions

The objectives to be considered in this study are maximizing students' performance in mathematics, minimizing the percentage of students under the basic level and maximizing teachers' satisfaction index, all of them normalised. The econometric study has allowed us to express these outcomes as functions of a set of variables, obtaining the linear coefficients shown in table B1 (Appendix B). The coefficients corresponding to missing flags variables were not considered in this analysis. Therefore, if we rename the variables as x_k, $k = 1, \ldots, 19$ (only in this subsection, for the sake of clarity), $\hat{\beta}_k^j$ is the regression coefficient of variable K for performance level j, and $\hat{\alpha}^j$ is the independent term of performance level j, then we have the following 3 objectives:

$$EP_j(\boldsymbol{x}) = \left(\hat{\beta}^j\right)^T . \mathbf{x} + \hat{\alpha}^j \quad j = 1,2,3. \qquad (6)$$

where $\left(\hat{\beta}^j\right)^T = (\hat{\beta}_1^j, \hat{\beta}_2^j, \ldots, \hat{\beta}_{19}^j)$ and $\boldsymbol{x} = (x_1, x_2, \ldots, x_{19})^T$, which measure the expected performance in mathematics, the expected percentage of students under the basic level and the expected teachers' satisfaction index. The resulting multiobjective problem to be solved in each case is the following:

$$Max\ (EP_1(\boldsymbol{x}), -EP_2(\boldsymbol{x}), EP_3(\boldsymbol{x})) = \left(\left(\hat{\beta}^1\right)^T . \mathbf{x} + \hat{\alpha}^1, -\left(\hat{\beta}^2\right)^T . \mathbf{x} - \hat{\alpha}^2, \left(\hat{\beta}^3\right)^T . \mathbf{x} + \hat{\alpha}^3\right) \qquad (7)$$

Subject to: (C1) – (C13)

Thus, the model under scrutiny is a mixed integer quadratic multiobjective model with 3 objectives, 19 variables and 13 technical constraints. To solve any multiobjective problem, it is usual to consider all the objective functions in the same sense (maximize or minimize) since that to minimize any objective function is equivalent to maximize the opposite one. In our case, we have changed the sign of the second objective function taking into account the formulation of the section 5.1.

For each case, we have calculated their ideal values:

$$z^* = (539.938, 0.029, 14.522)$$

These ideal values, in teacher level, are 539.938 points of students' average score, 2.9% of students performing under the basic level and a score of 14.522 in the teacher satisfaction index.

5.5. Solutions of the Multiobjective models

As previously mentioned, the multiobjective problem has the aim of detecting the profile of the most balanced teacher in terms of these three selected outcomes. To this end we have used a reference point approach, where the ideal values for each of the dependent variables have been obtained from the actual teachers who took the TIMSS survey in Spain. In particular, the related characteristics of teacher who gets the best values for the three objectives is the following: the students of this teacher obtain an average score of 568.590, the proportion of students under the basic level is 0% and the value of the teacher satisfaction index is 13.390. Besides, note that these objectives are not in the same scale, what means that normalization is needed in this formulation.

Furthermore, using these three objectives which belong to an actual teacher makes this analysis more realistic, because these reference points are achievable to the extent that there is one teacher who gets each of them. To sum up, the reference values are:

$$q_1 = 568.590, \ q_2 = 0, \ q_3 = 13.390$$

The normalised reference points are:

$$q_1 = 2.220,\ \ q_2 = -0.730,\ \ q_3 = 1.140$$

Consequently the reference point problem solved is:

$$Minimize \qquad \alpha + \rho \sum_{j=1}^{3} \left(q_i - \left(\hat{\beta}^j \cdot \mathbf{x} + \hat{\alpha}^j \right) \right)$$

$$Subject\ to\colon q_j - \left(\hat{\beta}^j \cdot \mathbf{x} + \hat{\alpha}^j \right) \le \alpha \qquad j = 1, 2, 3 \qquad (8)$$

(C1) – (C13)

When formulating this problem, all the criteria are equally weighted, meaning that it is implicitly assumed that the achievements of all the reference levels have the same importance for the decision maker. The solutions obtained after solving the previous problem are shown in Table 5.3.

Table 5.3

Solutions for the multiobjective model

Decision Variables	
Variables	***Solution***
d1	0
d2	0
b1	0
b2	0
b3	1
und1	0
und2	0
und3	1
c1	0
c2	0
c3	1
spec1	0
spec2	0
spec3	0
evach	1
yexp	21.747
yexp2	472.932
male	0
saf	1

Objective functions		
Subject	***Value***	***Reference***
Average Mathematics Score	539.938	568.590
Proportion of students under basic level	0.037	0
Teacher Satisfaction Index	13.623	13.390

Source: Authors' own calculations.

The results presented in this table provide a “taxonomy” of the best and more balanced teachers, in terms of the average score of their students, proportion of students under basic level and teacher satisfaction index. Analyzing the solutions generated, it is remarkable that multiobjective programming is able to detect some issues that can hardly be obtained only with the econometric analysis.

In summary, regarding to the results presented in Table 5.3, we could conclude that when teachers do not have students with diglossia they obtain better and balanced optimum results in the three dependent variables. This also happens when the proportion of students with 100 or more books is higher than 42.5%, the proportion of students who say that their teacher is easy to understand is higher than 95.5% and the proportion of students who are congratulated by their teacher surpass 76.5%. Thus, for these categories the upper bounds of the variables seem to work in the same direction. When the directors of the centre where the teachers work think that there is not a lack of teachers in their school has the same effect, or when the evaluation methods used at the school are based on students' achievements. Those teachers with a number of years of experience around the median value and/or who feel very safe at their school also contribute to a better level of balanced outcomes. Last, but not least, being a female teacher helps to achieve this balanced optimum.

5.6. Robustness of the solutions

In addition to the previous analysis, we have also evaluated the robustness of the solutions by changing the weights of the reference values and the confidence level for the constraint intervals. In the case of the weights, the solution did not change when each weight at the time was increased by one unit, what is denoting that solutions are robust with respect to these parameters[9].

In the case of the confidence intervals for the dependence constraints for the pair of variables, they have been changed to a 95% confidence interval, but the values of the objective functions changed slightly: variables '*yexp*' and '*yexp2*' turned into 21.375 and 456.891 with respect to those in Table 5.3, so they were not very influenced by this variation. The biggest difference in the values of the objective functions with respect to 99% confidence intervals is insignificant (average scores in mathematics changed from 539.938 to 539.691, while the other two dependent variables did not change when considering three decimals, which is the criteria followed in this study), thus meaningless.

6. Conclusions

In this study a multiobjective approach has been carried out as a way of complementing an econometric analysis regarding three outcomes at the teacher level: average scores in mathematics, the proportion of students who perform under the basic level and teacher satisfaction index. The econometric analysis has allowed us to determine the significant parameters which relate the outcomes to many inputs and, then, a multiobjective approach has contributed to the identification of the desirable profiles of teachers who reach good and balanced outcomes, as well as the determination of policies that may be carried out in order to improve their performance.

[9] For reasons of space the corresponding table is not presented, but it may be supplied upon request to the authors.

From a methodological point of view, the use of a reference point approach has helped us to generate efficient solutions and, at the same time, to get compensated solutions.

This study thus provides a contribution to the development of education policies, particularly interesting in a context of economic crisis when the budget assigned to education has been cut. The results obtained can be translated into suggestions for teachers and the education system in general. In this sense, teachers should take care of the way they communicate their knowledge to their students and also congratulating them as a feedback, when they are performing correctly. The lack of teachers at schools to cover all lessons could be harmful to the achievement of these objectives, so it would be necessary to solve this problem before beginning with the course. Teachers' experience is also an important issue, because years of experience affects positively to achieve the different outcomes, although till certain threshold; then, they could have a negative effect (inverted U shape). In addition, policy makers should be more concerned with the need to promote some cultural habits, concretely, promoting reading habits by raising conscience to parents about the importance of books, through, e.g., advertising campaigns. Teachers also play an important role in promoting reading habits among students and interacting with their parents on this issue. Finally, the feeling of safety of teachers, in the field of their personal integrity and also in their job conditions, has a very positive influence on the achievement of the three objectives. Consequently creating a comfortable working environment should be a key principle in every school.

We can conclude that national policies and practices related to improving teacher satisfaction appear to be a promising area for future research to identify how other countries have achieved both excellence and equity in student achievement.

Appendix A

Table A1

Labelling of the variables analysed

Name	*Notation*	*Variable*	*Type*	*Values*	*Description*
maths	y_1	**Performance in mathematics**			
		Not normalised	Cont.	[353.380,568.590]	Student's marks (points) in mathematics.
		Normalised	Cont.	[-3.550,2.220]	Normalised student's marks in mathematics.
undbas	y_2	**Percentage of students under the basic level**			
		Not normalised	Cont.	[0,0.840]	Percentage of students who perform under basic level (400 points).
		Normalised	Cont.	[-0.730,4.870]	Normalised percentage of students who perform under basic level (400 points).
tchsat	y_3	**Teachers' satisfaction index**			
		Not normalised	Cont.	[3.550, 13.390]	TIMSS' Teachers' Career Satisfaction Index.

		Normalised	Cont.	[-3.460,1.140]	Normalised TIMSS' Teachers' Career Satisfaction Index.
		Proportion of students with diglossia			Proportion of students whose language is different from that of the test (diglossia). *Reference: 0% of students with diglossia.*
d1	x_1	More than 0% to 12%	Bin.	0 or 1	The proportion of students with diglossia is more than 0% and less or equal to 12%.
d2	x_2	More than 12%	Bin.	0 or 1	The proportion of students with diglossia is more than 12%.
		Proportion of students who have 100 or more books at home			Proportion of students who have 100 or more books at home. *Reference: 13.5% or less.*
b1	x_3	More than 13.5% to 27.5%	Bin.	0 or 1	The proportion of students who have 100 or more books at home is more than 13.5% and less or equal to 27.5%.
b2	x_4	More than 27.5% to 42.5%	Bin.	0 or 1	The proportion of students who have 100 or more books at home is more than 27.5% and less or equal to 42.5%.
b3	x_5	More than 42.5%	Bin.	0 or 1	The proportion of students who have 100 or more books at home is more than 42.5%.
		Proportion of students who say that their teacher is easy to understand			Proportion of students who say that their teacher is easy to understand. *Reference: 80% or less.*
und1	x_6	More than 80% to 89%	Bin.	0 or 1	The proportion of students who say that their teacher is easy to understand is more than 80% and less or equal to 89%.
und2	x_7	More than 89% to 95.5%	Bin.	0 or 1	The proportion of students who say that their teacher is easy to understand is more than 89% and less or equal to 95.5%.
und3	x_8	More than 95.5%	Bin.	0 or 1	The proportion of students who say that their teacher is easy to understand is more than 95.5%.
		Proportion of students who are congratulated for their work in maths by their teacher			Proportion of students who are congratulated for their work in maths by their teacher. *Reference: 59% or less.*
c1	x_9	More than 59% to 68.5%	Bin.	0 or 1	The proportion of students who are congratulated for their work in maths is more than 59% and less or equal to 68.5%.
c2	x_{10}	More than 68.5% to 76.5%	Bin.	0 or 1	The proportion of students who are congratulated for their work in maths is more than 68.5% and less or equal to 76.5%.
c3	x_{11}	More than 76.5%	Bin.	0 or 1	The proportion of students who are congratulated for their work in maths is more than 76.5%.
		Directors' opinion about the lack of teachers with a specialization in the school in mathematics			Directors' opinion about the lack of teachers with a specialization in the school in mathematics. *Reference: Not a problem at all.*
spec1	x_{12}	A Little	Bin.	0 or 1	Teachers whose director agrees a little about the lack of teachers with specialization in mathematics in the school.
spec2	x_{13}	Some	Bin.	0 or 1	Teachers whose director agrees about the lack of teachers with specialization in mathematics in the school.
spec3	x_{14}	A lot	Bin.	0 or 1	Teachers whose director agrees a lot about the lack of teachers with specialization in mathematics in the school.
evach	x_{15}	**Evaluation of teachers: Student achievement**	Bin.	0 or 1	Method of teachers' evaluation at school: Students' achievement. *Reference: Other different evaluation method.*
yexp	x_{16}	**Years of experience**	Cont.	[0,41]	Teachers' years of experience as a teacher.
yexp2	x_{17}	**Squared years of experience**	Cont.	[0,1681]	Squared teachers' years of experience as a teacher.
male	x_{18}	**Gender of teacher: Male**	Bin.	0 or 1	Gender of teacher: Male. *Reference: Female.*
		Teacher opinion about the statement of feeling safe at school			Teacher's opinion about the statement of feeling safe at school. *Reference: Agree a little, disagree a little, disagree a lot (grouped in "not agree a lot").*
saf	x_{19}	A lot	Bin.	0 or 1	Teacher feels very safe at school.

Source: Compiled by authors for TIMSS 2011 Spain.

Table A2
Descriptive Statistics for TIMSS 2011 Spain

		Mean scores in maths				Students with scores under the basic level (<400)				Teachers' Satisfaction Index			
		Mean	Stand. Dev.	Min. value	Max. value	Mean	Stand. Dev.	Min. value	Max. value	Mean	Stand. Dev.	Min. value	Max. value
Proportion of students with diglossia	**0%**	496	37.17	387	569	0.08	0.12	0	0.71	11.11	2.14	3.55	13.39
	More than 0% to 12%	486	35.22	353	544	0.1	0.15	0	0.84	10.84	1.99	5.74	13.39
	More than 12%	472	34.67	377	552	0.15	0.17	0	0.68	10.83	2.32	5.74	13.39
Proportion of students who have 100 or more books at home	**13.5% or less**	467	35.1	353	562	0.16	0.17	0	0.84	10.68	2.22	5.74	13.39
	More than 13.5% to 27.5%	474	40.76	377	552	0.16	0.18	0	0.71	10.62	2.38	5.74	13.39
	More than 27.5% to 42.5%	496	27.2	444	546	0.06	0.08	0	0.32	11.23	1.81	7.81	13.39
	More than 42.5%	509	27.47	427	569	0.04	0.07	0	0.33	11.32	2.07	3.55	13.39
Proportion of students who say that their teacher is easy to understand	**80% or less**	467	44.25	353	552	0.19	0.21	0	0.84	10.16	2.18	5.74	13.39
	More than 80% to 89%	487	32.25	409	550	0.09	0.11	0	0.53	10.99	1.96	5.74	13.39
	More than 89% to 95.5%	489	33.62	393	567	0.1	0.13	0	0.67	11.34	2.3	3.55	13.39
	More than 95.5%	497	34.11	402	569	0.06	0.11	0	0.47	11.2	2.11	5.74	13.39
Proportion of students who are congratulated for their work in maths by their teacher	**59% or less**	476	37.74	353	538	0.14	0.19	0	0.84	10.4	2.17	5.74	13.39
	More than 59% to 68.5%	490	34.81	418	567	0.09	0.1	0	0.42	10.59	2.36	3.55	13.39
	More than 68.5% to 76.5%	483	36.05	393	562	0.11	0.15	0	0.67	10.82	1.99	6.52	13.39
	More than 76.5%	496	38.14	377	569	0.09	0.13	0	0.68	12.14	1.56	8.38	13.39
Directors' opinion about the lack of teachers with a specialization in the school in mathematics	**Not at all**	489	35.86	353	567	0.1	0.14	0	0.84	11.26	1.92	5.74	13.39
	A little	476	35.03	408	537	0.13	0.13	0	0.53	10.76	2	6.52	13.39
	Some	489	42.18	377	562	0.11	0.17	0	0.68	9.9	2.67	3.55	13.39
	A lot	474	45.51	402	522	0.13	0.17	0	0.4	10.27	2.17	8.38	13.39
Evaluation of teachers: Student achievement	**Yes**	490	33.42	377	567	0.09	0.11	0	0.68	10.85	2.14	3.55	13.39
	No	476	46.2	353	569	0.16	0.21	0	0.84	11.42	2.01	6.52	13.39
Years of experience	**Less than 12**	475	35.08	377	533	0.14	0.17	0	0.71	11.27	2.28	5.83	13.39
	Between 13 and 21	486	42.9	353	567	0.1	0.18	0	0.84	10.96	1.74	7.81	13.39
	Between 22 and 30	493	39.72	409	562	0.1	0.14	0	0.53	10.58	2	5.74	13.39
	Between 31 and 41	491	27.71	444	569	0.08	0.08	0	0.32	10.87	2.51	3.55	13.39
Gender of teacher: Male	**Female**	485	38	353	569	0.11	0.15	0	0.84	11.05	2.13	3.55	13.39
	Male	490	33.63	408	549	0.09	0.14	0	0.53	10.64	2.15	6.52	13.39
Teacher opinion about the statement of feeling safe at school*	**Agree a lot**	490	36.34	377	569	0.1	0.14	0	0.68	11.36	1.93	5.83	13.39
	Agree a little	478	35.58	353	550	0.12	0.15	0	0.84	9.86	2.37	3.55	13.39
	Disagree a little	439	35.63	387	481	0.3	0.23	0.14	0.71	9.07	0.95	7.81	10.13
Total Non-Normalised		486	37.08	353	569	0.11	0.15	0	0.84	10.95	2.14	3.55	13.39
Total Normalised		0	1	-3.55	2.22	0	1	-0.73	4.87	0	1	-3.46	1.14

Note *: Nobody answered "Disagree a lot" to this question.

Source: Authors' own calculations from TIMSS 2011 in fourth grade, Spain.

Appendix B

Table B1

OLS estimates of the normalized mathematics' achievement, percentage of students under basic level and teacher satisfaction index

	Normalised scores in mathematics	Normalised % of students under basic level (<400)	Normalised teacher's satisfaction index
Proportion of students whose language is different from that of the test (diglossia). *Reference: 0% of students with diglossia*			
0% to 12%	-0.444***	0.211	-0.076
	(0.147)	(0.155)	(0.164)
> 12%	-0.531***	0.281*	-0.108
	(0.152)	(0.161)	(0.169)
Proportion of students who have 100 or more books at home. *Reference: 13.5% or less*			
13.5% to 27.5%	0.080	0.016	-0.007
	(0.168)	(0.178)	(0.188)
27.5% to 42.5%	0.599***	-0.556***	0.283
	(0.177)	(0.187)	(0.198)
> 42.5%	0.778***	-0.500***	0.230
	(0.180)	(0.190)	(0.201)
Proportion of students who say that their teacher is easy to understand. *Reference: 80% or less*			
80% to 89%	0.448**	-0.606***	0.221
	(0.174)	(0.185)	(0.195)
89% to 95.5%	0.544***	-0.600***	0.420*
	(0.192)	(0.203)	(0.214)
> 95.5%	0.659***	-0.750***	0.308
	(0.184)	(0.195)	(0.205)
Proportion of students who are congratulated for their work in maths by their teacher. *Reference: 59% or less*			
59% to 68.5%	0.207	-0.163	-0.115
	(0.173)	(0.183)	(0.193)
68.5% to 76.5%	-0.073	0.030	-0.084
	(0.178)	(0.188)	(0.199)
> 76.5%	0.195	-0.036	0.598***
	(0.185)	(0.196)	(0.207)
Directors' opinion about the lack of teachers with a specialization in the school in mathematics. *Reference: Not a problem at all*			
A Little. Miss	-0.320*	0.233	0.046
	(0.170)	(0.180)	(0.190)
Some. Miss	0.124	-0.048	-0.467**
	(0.176)	(0.187)	(0.197)
A lot. Miss	-0.693*	0.342	-0.656
	(0.387)	(0.409)	(0.432)
Evaluation of teachers: Students' achievement. *Reference: Other different method.* Miss			
	0.318**	-0.420***	-0.227
	(0.147)	(0.155)	(0.164)
Years of experience. Miss	0.061***	-0.024	-0.041
	(0.022)	(0.024)	(0.025)
Squared years of experience. Miss	-0.001**	0.000	0.001
	(0.001)	(0.001)	(0.001)
Gender of teacher. *Reference: Female*			
Male. Miss	0.150	-0.125	-0.248
	(0.151)	(0.160)	(0.169)
Teacher opinion about the statement of feeling safe at school. *Reference: Agree a little, disagree a little, disagree a lot (grouped in "not agree a lot"). Miss*			
A lot. Miss	0.422***	-0.218	0.651***
	(0.143)	(0.152)	(0.160)
Constant	-1.576***	1.186***	-0.035
	(0.310)	(0.328)	(0.346)
Observations	190	190	190
R-squared	0.466	0.375	0.346

Source: Authors' own calculations from TIMSS 2011 in fourth grade, Spain.

OLS estimates. Standard errors in brackets. Dependent variable: Normalised mean scores in mathematics, normalised percentage of students who performed under the basic level and normalised teachers' satisfaction index. Missing flag variables where included for those variables with less than 190 observations. Only the missing flags for the proportion of students who have 100 or more books at home and evaluation of teachers based on students' achievement were highly significant for normalised scores in mathematics and normalised percentage of students under basic level.

Reference group: Reference categories are indicated in each variable. *** significant at 1%, ** significant at 5%, * significant at 10%.

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