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Article

Factors Influencing Teachers' Use of ICT in Class: Evidence from a Multilevel Logistic Model

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Abstract: Information and Communication Technologies (ICTs) have become a key factor in the educational context, especially in the aftermath of the COVID-19 pandemic, and, correctly implemented, can help to improve academic performance. The aim of this research was to analyse the factors that influence teachers' decisions to use ICT more- or less frequently to carry out tasks and exercises in their classes. To this end, we estimated a multilevel logistic model with census data from the individualized evaluation of students of the Community of Madrid (Spain) carried out at the end of the 2018–2019 academic year in primary and secondary education. Additionally, we applied multiple imputation techniques to deal with missing values. Based on our results, we found that motivated teachers who have received ICT training, teach calm and respectful classes, and work at schools where students have access to digital devices and frequently use ICT at home, have a high predisposition to use ICT in their classes. Considering our results, our recommendations are aimed at improving teacher training in ICT, encouraging a frequent but responsible use of ICT at home, and increasing the provision of technological resources in schools.

Keywords: ICT; logistic regression; multilevel or hierarchical model; multiple imputation; teaching

MSC: 62; 91

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1. Introduction

The incorporation of Information and Communication Technology (ICT) into the educational process offers numerous advantages. In this sense, the implementation of ICT in classes to complement traditional teaching methods is associated with greater student motivation thanks to the use of more attractive, entertaining, and fun tools [1,2]. Likewise, ICT enables greater interactivity in learning, with more opportunities for cooperation and an improvement in communication between teachers and students [3]. ICT also stimulates initiative and creativity [4,5] and facilitates the individualization and flexibilization of education [6]. These advantages, among others, can improve students' acquisition of knowledge and have a positive influence on students' academic performance.

Despite all the potential advantages of using ICT for educational purposes in classes, the use of ICTs for educational purposes in the Autonomous Community of Madrid (Spain) is modest, and there is still room to increase their frequency of use (see descriptive statistics in Section 3.2). In this regard, considering that the integration of ICT for educational purposes in classes is ultimately decided by the teacher of each subject, it is of great interest to analyse what factors determine whether a teacher is more or less conducive to the use of these tools. Specifically, the aim of this research is to determine the personal characteristics of teachers, as well as those of the school and class environment, which make them more likely to use ICT in their classes. This information will allow us to elaborate recommendations for policy makers and school principals oriented to increase the frequency of use of ICTs in classes in order to take advantage of all the potential benefits that the use of these tools entails. Additionally, given the effects of the COVID-19 health crisis in the educational context, it is expected that the understanding of the relationship between ICT and education will have changed following the need to move to online-only teaching during the months of home confinement from March 2020. In this sense, the results achieved in this research can serve to appropriately guide measures regarding the use of ICT in education in a post-pandemic world where these tools could become more prominent in classes.

With regard to the methodology used in this research, we estimated multilevel logistic models with census data from individualized evaluations carried out in the Autonomous Community of Madrid at the end of the 2018–2019 academic year in three different educational levels: the 3rd year of primary education, 6th year of primary education, and 4th year of secondary education. In order to estimate the parameters of interest, we adopted the maximum likelihood method. The dependent dichotomic variable is defined as the "use of ICT resources to carry out projects or do exercises in class" and can take values 0 (indicates that ICTs are not used or are only occasionally used) or 1 (indicates that ICTs are used frequently or always). As explanatory variables, we considered 20 variables relating to student characteristics, student groups, teachers, and schools. Considering that we were working with large sample sizes, we followed [7] and opted for the estimation of a binomial logistic model instead of other statistical techniques that also allow for the analysis of dichotomous variables (probit or log-log models). Additionally, the estimation of a logit allows a simpler interpretation of the coefficients obtained in terms of odd ratios, a common measure of effect size for proportions. Moreover, we used multiple imputation techniques to overcome the problems of missing values in the databases we worked with. All statistical analyses were performed with Stata 14 software.

This research is novel and supposes a contribution to the previous literature for five fundamental reasons: (1) the scarce attention given in literature to date to the factors that determine the frequency of ICT use in the classes; (2) the analysis of potentially explanatory factors for the frequency of ICT use that have not been explored in previous studies (e.g., level of disturbance in the class); (3) comparative analysis by educational levels; (4) the use of an administrative census database with enough respondents to have a high degree of statistical confidence in the survey results; and (5) the possibility of linking students and teachers, something which, as explained in the Materials and Methods Section 3.1, is not possible in other databases.

Our results suggest that the use of ICT in classes by teachers is influenced by variables of a personal nature (e.g., motivation and ICT training), by variables related to the class environment (e.g., disruptive behaviours and students' ICT use at home), and by the school climate (e.g., lack of technological devices). Most of the determinants are common for all the educational levels, but we also found different results by educational levels for some of the studied variables.

The paper is structured as follows. Section 2 presents a review of previous literature about the factors that affect the frequency of use of ICT by teachers in their classes. Section 3 describes the data and variables used in the analysis and the methodological approach. Section 4 presents the results of the empirical analysis, and Section 5 concludes with the final considerations reflecting on the main research findings and suggesting recommendations for policy makers and school principals, as well as future lines of research.

2. Literature Review

Information and communication technologies (ICTs) can complement, enrich, and transform education. That is why, since their incorporation into the educational field, they have come to be considered as an additional factor in the analysis of the determinants of academic performance [8–10]. As mentioned in the introduction, the use of ICT in classes is associated with a number of potential advantages [1–6] that could lead to improved student competence and better academic performance.

Considering the relevance of ICT, some previous studies have focused on assessing the factors that affect teachers' decisions to use ICT more- or less frequently in their classes. The following is a detailed analysis of previous research in this area. Specifically, considering our object of study, we focus on previous studies that have analysed these factors in the context of primary and secondary education. As can be seen in the literature review presented below, there have been few studies on our object of research in recent years. For this reason, and considering the pace at which ICTs are evolving, our research is relevant and provides novel and updated empirical evidence on the factors influencing teachers' frequency of use of ICT in the classes.

Previous research in this area categorizes factors that affect the frequency of use of ICT by teachers into two main groups: (i) personal characteristics of teachers, and (ii) external environment. Regarding the personal characteristics of teachers, previous studies suggest that teachers' personal characteristics can influence the adoption of an innovation such as ICT [11,12]. In this line of research, [13] develops a research-based path model to explain causal relationships between different factors and technology integration in the classes. They find that teachers' demographic characteristics (years of teaching and age) negatively affect their technology integration in the classes, while teachers' computer proficiency positively affects their technology integration. Considering different psychological factors, [14] analyses Chinese primary school teachers and finds that motivation variables have a direct effect on the implementation of ICT in classes. In Spain, [15] finds that teachers' personal use of ICTs is key to explaining their frequency of use of these tools in their classes. In Norway, [16] finds that teachers' perceived usefulness of ICT is positively related to the use of ICTs, whereas age is negatively related to it. In the same vein, [17] shows that in Korean elementary schools, teachers' aptitude, disposition, and attitudes toward ICT are the main determinants of teachers' use of ICT in classes for educational purposes. The authors of [18] carried out multiple regression analyses of the frequency of computer use by teachers for instruction in five countries (the Netherlands, Denmark, Australia, Poland, and Germany) and found that antecedents concerning teachers' attitudes have more of an impact on the teachers´ use of ICT in classes than school characteristics. In the Czech Republic, [19] shows, using a multilevel approach with ICILS (2013) data, that the self-efficacy of teaching staff plays a key role in implementing ICT in the lessons. In Chile, [20] used data from a questionnaire administered to teachers and found that their decision to use ICT in classes mainly depends on their perceptions of ICT impact on professional practice and that less experienced teachers use ICT more frequently. More recently, [21] built a structural equation model with data from Swiss primary schools and found that educational technology integration is dependent on the readiness of individual teachers based on perceived skills and beliefs.

In summary, the mentioned studies show that the personal characteristics of teachers are key to determining the frequency of use of ICTs in the classes. In this sense, based on the review carried out, it seems that the factors most commonly indicated as determining the use of ICT in classes are those related to teachers' aptitude, disposition, and attitudes toward ICT.

Although the pre-existing literature in this area has focused mainly on the factors related to individual characteristics of the teachers, there is also previous research that has studied the teachers' external environment, i.e., analysing how the characteristics of the class and school influence the teachers' decisions to implement ICT. In this line, [13] analysed data from Tennessee public school teachers and found that school-level factors, such as technical- and overall support, positively affect teachers' technology integration. The authors of [22] also show, by means of a multilevel regression model, that characteristics at the school level (ICT equipment of schools, school leadership, and aspects of school goals and educational strategies) do play a major role in the integration of ICT into teaching and learning of mathematics in the five educational systems analysed (Australia, Germany, the Netherlands, Norway, and Singapore). In Germany, [19] finds that pedagogical ICT support seems to be crucial for the use of ICT as a teaching tool. The authors also show that in Australia the participation of teaching staff in professional development activities organized by the school can be identified as relevant to determine the frequency of use of ICTs in the classes. More recently, [21] finds that the use of ICT in lessons in Swiss primary schools is influenced by the educational technology resources in classrooms, the perceived importance of technology integration in schools, goal clarity, head teacher support, as well as formal and informal exchange among teachers.

As this section has shown, although there are some previous studies on the object of research of this paper, literature in this area is limited. Therefore, we believe that it is crucial to extend research in this area and, based on the results, to develop relevant recommendations aimed at increasing the frequency of ICT use in classes in view of its potential benefits on academic performance.

3. Materials and Methods

3.1. Data: Individualized Evaluations for the Community of Madrid

Individualized evaluations are carried out annually for all students in schools in the Community of Madrid at the end of the 3rd year of primary education (8–9 years old), 6th year of primary education (11–12 years old), and 4th year of secondary education (15–16 years old). The purpose of these evaluations is to verify the degree of acquisition of linguistic (English and Spanish) and mathematical competence in all courses, science and technology competence in the 6th year of primary education, and social and civic competence in the 4th year of secondary education. In addition to the test carried out by the students for each of the previously mentioned competences, the school principals, teachers, families, and students completed a context questionnaire that served to evaluate social, economic, and cultural factors. Given the object of our research, we worked with the context questionnaires answered by students and their families, teachers, and school principals. These context questionnaires included a number of variables (see Section 3.2) that could potentially reflect factors explaining the decisions of teachers on the frequency of use of ICT in the classes.

One of the great advantages of this database is that it allowed us to link students and teachers. That is, we could find which specific students were taught by which teacher. This is not possible, for example, in the prestigious PISA educational database, so the possibility of linking students and teachers was an important novelty and consequently allowed us to carry out a rigorous analysis. In this sense, in this research we were interested in using student characteristics, among other factors, to find if they affect the teacher's likelihood to use ICTs in the classes. Knowing the specific students in each teacher's class allowed us to guarantee the appropriateness of the analysis, since, for example, if there were two teachers of the same subject in the school, we could know which group of students each teacher was teaching.

In this research we used data from the individualized evaluations carried out at the end of the 2018–2019 academic year in the Community of Madrid in the three corresponding educational levels previously mentioned. These were the most recent data available, since in the 2019–2020 and 2020–2021 academic years the test could not be performed due to the COVID-19 health crisis. The data are of a census nature, given that all students, teachers, and school principals from public, semiprivate (privately owned but publicly-funded), and private schools participated in these evaluations. The student, teacher, and school participation data were as follows: (1) in the 3rd year of primary school, a total of 69,977 students and 6310 teachers from 1320 schools; (2) in the 6th year of primary school, a total of 69,355 students and 7917 teachers from 1308 schools; and (3) in the 4th year of secondary school a total of 62,165 students and 5775 teachers from 803 schools. Although the number of initial observations is high as it is from census data, the data set presents a significant problem of missing values that led to a significant reduction in the number of final observations initially included in our models (see Section 3.3).

3.2. Variables and Descriptive Analysis

The variables considered for the statistical analyses are detailed in this section. First, being that the objective of our research was to clarify the determinants of the educational use of ICT by teachers in their classes, the dependent variable is defined as the "use of ICT resources to carry out projects or do exercises in class". This variable was obtained from the teachers' context questionnaire and can take values 0 (indicates that the ICTs are not used or are only occasionally used) or 1 (indicates that the ICTs are used frequently or always). As explanatory variables we used different information from the context questionnaires completed by students and their families, teachers, and school principals. The selection of explanatory variables was carried out based on previous literature and considering those factors that we believed could potentially have an impact on the decision of the teacher to more- or less frequently use ICTs in classes. In addition, it is important to specify that the correlation matrix between all the dependent and independent variables was calculated, and that we did not include variables showing a correlation coefficient higher than 0.4. That is, all the research variables included in each of the models estimated for the three different educational levels had correlation coefficients, with the rest of the variables used in that model lower than 0.4.

From the student and family questionnaire, we included information on the student's gender; whether the student was born in Spain or abroad; grade repetition (only available in 6th year of primary education and 4th year of secondary education); the number of books at home (as a proxy of the socio-economic status); the frequency of use of a computer and tablet at home; and the total number of students per class (class size). The variable "total number of students per class" was created manually from the centre and group codes indicated in the student questionnaire. From the teachers' questionnaires, we included the following as explanatory variables: teacher's gender; year of birth; school ownership; time dedication; ICT training received in the last 12 months; disturbance of order in class; satisfaction with the profession (proxy of motivation); and the subject taught. Regarding the "school ownership" variable, although it refers to a characteristic of the school, it has a lower percentage of missing values in the teachers' questionnaires than in the principals' questionnaires, so it was decided to obtain it from the teachers' questionnaires. Finally, from the school principals' questionnaires, we included three explanatory variables: lack of a teacher training plan; lack of autonomy to make decisions; and lack of digital devices for teaching.

The explanatory variables previously enumerated can be subdivided into two main groups: variables directly of interest and other independent variables. Those variables directly of interest are the ones we initially considered could be highly related to the use of ICT in classes because they are directly related to these tools: teachers' ICT training, lack of digital devices in the school, and use of computers and tablets by students and their families at home. The rest of the variables are classified as other independent variables, as we included them in our regressions because we considered that they could somehow influence the teacher's decision to use ICT more- or less frequently, but to a lesser extent than those directly of interest, since they seem to have a less direct relationship. Nevertheless, the results of our research confirm that some of these independent variables are determining factors that greatly affect the decision to use or not use ICT in the classes.

Table A1 of the Appendix A presents the exact definition of each of the variables included in the statistical analyses of this research. Tables A2–A4 in the Appendix A show the main descriptive statistics of the dependent and independent variables of our analysis for the three educational levels analysed, as well as the percentage of missing values that was taken into consideration for the imputation process (Section 3.3). The descriptive statistics in Tables A2–A4 show some relevant characteristics of the schools, teachers, and students regarding the dependent variable and the variables directly of interest of this research. Firstly, with regard to the use of ICT resources to carry out projects or do exercises in class, it was observed that, regardless of the level of education that we analysed, the use of ICT was modest, given that there was still a high percentage of teachers who answered that they never or hardly ever use ICT in their classes. Therefore, there is scope to increase the frequency of ICT use for educational purposes in classes in order to take advantage of all the potential benefits that these tools present. If we focus on comparing levels of ICT use by educational levels, we observe that the educational level at which ICTs are most frequently used is the 6th year of primary education (65%), followed by the 4th year of secondary education (57%), and in last place the 3rd year of primary education (52%).

In relation to the variables classified as directly of interest, a relevant result is that only about half of all teachers at the different educational levels indicated that they had received ICT training in the previous 12 months. Considering that ICTs are tools that evolve quickly and require continuous training in their use, this result suggests that in our specific case of analysis, the Community of Madrid, there is still a high percentage of teachers who have not recently participated in ICT training activities and therefore may not be adequately trained to use them or to take full advantage of their use. Regarding the use of ICTs in students' homes, it is observed that in most homes ICTs are used frequently, every day or almost every day. Only about 5% of the students or families stated that ICTs are never or infrequently used at their home. Finally, regarding schools' characteristics, although few teachers considered the lack of technological resources to be a serious problem, we found that only a 39% of principals stated that they considered that there was no problem with the lack of availability of digital resources in their schools. These results indicate that there is still significant room for improvement in the availability of ICT resources in schools.

3.3. Missing Values and Imputation

The microdata we worked with in this research presented a significant problem of missing values. Therefore, despite them being data of a census nature, and having summoned all the students, families, teachers, and school principals of the Community of Madrid to carry out these evaluations, the students, families, teachers, and principals who were finally included in our estimates were much fewer than those officially enrolled in the different courses. This loss of observations is because we found some questions of interest in our research that were not answered by a high percentage of students, families, teachers, and school principals. That is, there were students, families, teachers, and principals who did not answer some of the questions in the context questionnaires that we included in our estimations, and were therefore initially excluded from our estimates.

The percentage of missing variables for each of our questions of interest is reflected in the last column of Tables A2–A4. As can be seen, the variables with the highest percentages of missing values are those from the students' and families' questionnaires. However, in the teachers' questionnaires—with the exception of the ICT training variable—and the principals' questionnaires, very low percentages of missing values were found. In summary, there are five variables with high percentages of missing values: immigrant, repeater, books at home, use of ICT at home, and ICT training. In the following, we explain how we proceeded in this situation of missing values, justifying all the statistical analyses performed. Although, for the sake of brevity, the tables with the results of the different tests performed in the missing value imputation process are not presented: they are available upon request to the authors.

In the presence of missing values, there were different ways to proceed. A first option was to ignore these missing values and perform a complete case analysis, that is, to include in our regressions only the observations for which we had information on all the variables detailed in Section 3.2. However, as suggested by [23], complete case analysis was only appropriate if the percentages of missing values were less than 5% (as a rule of thumb) or if the missing mechanism was missing completely at random (MCAR). Our data did not satisfy the rule of thumb, since we had variables with percentages of missing values greater than 5%, and the results of Little's MCAR test [24,25] revealed that missing values at the student and teacher levels (the levels where we found percentages of missing values higher than 5%) were not MCAR because the p-value was less than 0.05 in all cases. Since it has been shown that an MCAR mechanism cannot be considered to exist, it was not appropriate to proceed with a complete case analysis that included variables with percentages of missing values greater than 5% and not MCAR.

Once it had been determined that the analysis of complete cases was not adequate, we analysed whether it would be appropriate to use imputation techniques that allowed replacing missing data with substituted values. The reason for imputation was to avoid losing observations because they contained missing values and to increase the power of statistical tests by increasing the number of final observations used. The first step of analysis to be carried out to assess the possibility of imputing the missing values was to determine if the missing values were Missing at Random (MAR) or Missing Not at Random (MNAR). To check this, we created a new indicator variable for each of our research variables with percentages of missing values greater than 5%. This variable took the value of 1 if an observation was missing that variable and 0 if it was not. Then, we ran a set of logit models and t-tests to examine if any of the other variables in the dataset predicted missingness. In the case of the student and family questionnaires, the results confirmed that some of the variables were statistically significantly associated with missingness of the following variables: immigrant, repeater, books at home, and computer/tablet use at home. For example, we found that worst performing students were more likely to decline to answer some questions (i.e., test scores predict missingness on another variable). As for the teachers' questionnaire, we also found that some of the variables were associated with missingness of the variable ICT training. In this sense, we found that, for example, teachers who never used ICT in their classes were more likely to decline to answer the question about ICT training (i.e., use of ICT in the class predicted missingness on ICT training). Therefore, our results suggest that our missing values (in the variables immigrant, repeater, books at home, use of ICT at home, and ICT training) were MAR, and that whether an observation was missing had to do with the values of some of the student's or teacher's observed variables.

Previous literature shows that there are alternatives methods for handling MAR [26]: case deletion, pairwise deletion, mean substitution, regression imputation, or multiple imputation. In this research, we opted for the use of the most popular and recommended method [26]: multiple imputation (MI). MI uses the distribution of the observed data to estimate a set of plausible values for the missing data. Specifically, considering that the variables we wanted to impute were categorical, we used the method of multiple imputation by chained equations [27] using the "mi" command in Stata 14. The imputation through this technique involves a sequence of univariate imputation methods with fully conditional specifications of prediction equations [28]. We imputed the five variables included in our models from the student, family, and the teacher questionnaires with a percentage of missing values higher than 5% (immigrant, repeater, books at home, use of ICT at home, and ICT training) from an empirical approach of an ordered logistic regression, and following [29] we decide to use five imputations (m = 5). After the imputation process, we performed imputation model diagnostics using the "midiagplot" command in Stata to compare the distributions of the observed, imputed, and completed values. The results of the imputation model diagnostics suggested a good overlap between observed and imputed data.

Despite having performed a careful imputation process that overcame the model diagnostics and allowed us to increase the number of total observations, considering that we had a high number of missing values, there could be a criticism that our final results are driven in large part by our imputation model rather than the observed data. To try to overcome this criticism and as a robustness test, in addition to estimating our main models with the imputed values, we performed the following analyses: (1) complete case analysis using only the variables with percentages of missing values lower than 5% (rule of thumb); and (2) complete case analysis including all the variables described in Section 3.2.

3.4. Methodology

In order to be able to analyse the factors that affect teachers' decisions to use ICT more- or less frequently in their classes, it is suitable to use maximum likelihood estimates, such as logit or probit. The main difference between logit and probit models lies in the assumption of the distribution of error terms in the model. Specifically, in a logit model, the errors are assumed to follow a standard logistic distribution, whereas in a probit, the errors are presumed to follow a normal distribution. Considering that we were working with large sample sizes, we followed [7] and opted for the estimation of a binomial logistic model. In addition, the estimation of a logit allows a simpler interpretation of the coefficients obtained in terms of odd ratios, a common measure of effect size for proportions. Nevertheless, the regressions were also estimated using the probit technique in order to test the robustness of our results. The probit results are available in Table A5 in the

Appendix A and confirm the results obtained by estimating a logit. Additionally, as explained in Section 3.3, results of complete case analyses are available in Tables A6 and A7 in the Appendix A. The results of these analyses suggest similar conclusions to those obtained in the main models of this research using the imputed values.

The multilevel structure of our data (e.g., students nested within classes and teachers, and classes and teachers nested within schools) and the use in our estimates of variables measured at different levels of the hierarchy made it appropriate to build models that consider this hierarchical structure since nesting may have led to a statistical dependency among the observations. In the presence of this statistical dependence, the ordinary estimation of a logit model may involve unbiased regression coefficients, but the standard errors associated with those coefficients may be biased and increase the probability of Type I errors, leading to incorrect conclusions regarding the statistical significance [30]. Multilevel regression techniques allow to control the hierarchical structure of the data and produce unbiased estimates of the standard errors [31].

Our objective in this research was to predict a teacher-level outcome variable (use of ICT in the class) from variables measured at the student, teacher, and school level. Considering that students are nested within classes/teachers, and classes/teachers are nested within schools, our dependent variable was placed at the intermediate level (teacher-level) and our objective was to estimate it as a function of both variables related to characteristics of a lower level (student) and a higher level (school). In multilevel modelling, when the dependent variable measured at the intermediate level (in our case, teacher-level) is predicted by variables measured at a higher level (school-level), it is referred to as a macro–micro situation. Contrarily, when the dependent variable defined at a higher group level (in our case, the teacher-level) is predicted or explained on the basis of independent variables measured at a lower level (student-level), it is referred to as a micro–macro situation. Therefore, in this research we were confronted with both a macro–micro situation and a micro–macro situation.

As far as macro–micro situations are concerned, these have been frequently studied in literature on multilevel modelling [32], and the statistical software we employed in this research (Stata 14) allowed us to control for this multilevel structure, which implies that teachers are nested in schools by means of the "melogit" command [33]. However, as far as the micro–macro situation is concerned, the models for micro–macro situations have been, until recently, mostly neglected in literature on multilevel modelling [34], and analysis techniques are scarce. We were therefore faced with two options traditionally used to deal with micro–macro situations: (1) aggregating the values of the variables measured at the student level by assigning to each teacher for that variable the mean or mode of the students' responses in his or her class; or (2) disaggregating the teachers' responses by assigning to each student the value of their teacher's response, so that all students in the same class shared the same value for the variables referring to their teacher. We decided to use the aggregation technique, since the disaggregation procedure violates one of the basic assumptions of regression analysis: the independent observations assumption [35]. This may result in downwardly biased standard error estimates, excessively large test statistics, and inflated Type I error rates [36]. However, using the aggregation technique, we eliminated the correlation among individual error terms. Nevertheless, it is important to note that the aggregation technique reduces the variability in the data, and this may also result in inappropriate estimates of the standard errors of the regression parameters [34]. For this reason, the results obtained for the variables related to student characteristics should be interpreted with caution.

There are six assumptions that underpin binomial logistic regression: assumption 1: dichotomous dependent variable that refers to two categories mutually exclusive and exhaustive; assumption 2: two or more independent variables measured at the continuous or nominal level; assumption 3: independence of observations; assumption 4: data must not show multicollinearity; assumption 5: a linear relationship between any continuous variables and the logit transformation of the dependent variable; and assumption 6: no significant outliers, high leverage points, or highly influential points.

The first two assumptions were automatically verified in this research since the dependent variable refers to two categories mutually exclusive and exhaustive (never or only occasionally uses ICTs versus always or frequently uses ICTs) and we included a total of 20 independent variables. As previously explained, the assumption of independence was violated in our dataset, but we dealt with this situation using a multilevel logit approach that properly accounted for this fact. In order to verify assumption 4, we tested the multicollinearity by using the "Collin" command in Stata 14 to obtain the Variance Inflation Factor (VIF) and the Condition Number. As evidenced in Table A8 in the
Appendix A, the VIF values are higher than 0.1 and lower than 5, and the Condition Numbers are lower than 10, which according to [37] are the values considered as a rule of thumb to indicate the existence of multicollinearity. Therefore, it can be concluded that the assumption of the absence of multicollinearity was satisfied.

As for assumption 5, after the estimation of the multilevel logit we used the link test for model specification and the Box–Tidwell test in order to verify it. The link test looks for a specific type of specification error called a link error wherein a dependent variable needs to be transformed to accurately relate to the independent variable. Specifically, the link test adds the squared independent variable to the model (hatsq) and tests for significance versus the non-squared model (hat). The Stata "Linktest" command was used and it was confirmed that there were no specification errors since, from the t-test for hatsq, we see that the squared term is not a significant predictor (see Table A9 in Appendix A). Additionally, the Box–Tidwell test allows to check for linearity between the predictors and the logit by adding log-transformed interaction terms between the continuous independent variables and their corresponding natural log into the model. We filtered our dataset to keep only the independent variables that could be treated as continuous, and we found that the interaction terms were not statistically significant and therefore there was linearity in the logit. For reasons of length, the results of the Box–Tidwell tests are not presented in this article but are available upon request. Finally, in relation to assumption 6, considering the nature of our data (ordinal and nominal categorical variables) and the descriptive statistics of the variables used in this research, the non-existence of outliers, high leverage points, or highly influential points is guaranteed.

Considering what has been explained in the previous paragraphs, we proceeded to estimate a multilevel logit using the "melogit" command in Stata in which the binomial dependent variable was the "use of ICT resources to carry out projects or do exercises in class" and the explanatory variables were those mentioned in Section 3.2 related to the students, teachers, and schools.

We consider that $X_i, for\ j = 1, ..., 20$ represents the different explanatory variables and Y refers to the dependent answer variable denoting whether a teacher uses ICTs or not in classes according to the following codification:

$$Y = \begin{cases} 0, \text{if the teacher never or only occasionally uses ICTs} \\ 1, \text{if the teacher frequently or always uses ICTs} \end{cases}$$

We then consider that $y = (y_i, \ldots, y_n)'$ is the observed answer vector, of dimension $n\ x\ 1$; x is the matrix of observed values for the explanatory variables, of dimension $n\ x$ (20 + 1) and $x_i = (1, x_{i1}, \ldots, x_{ip})'$ is a row vector of x, for $y_i \in \{0,1\}$ and $i = 1, \ldots, n$. In addition, we assume that the observed value y_i is a realization of the random variables $Y_i, for\ i = 1, \ldots, n$.

The dependent answer variable Y_i is a binary variable, so in order to link the explanatory variables X's to the groups, we assume the following logistic regression model:

$$Y_i \sim Binomial(1, p_i) \quad (1)$$

$$p_i = \mathrm{E}(Y_i|x_i) = \frac{exp\{\beta' x_i\}}{1 + exp\{\beta' x_i\}} \quad (2)$$

where $\beta = (\beta_0, \ldots, \beta_{20})$ is the parameter vector and p_i is the conditional probability of Y_i to assume value the value 1 with $0 \leq p \leq 1$, for $i = 1, \ldots, n$.

In our empirical work, taking the logarithm of the odds ratios we estimate the following logit function:

$$\text{logit}\ (p_i) = \ln\left(\frac{p_i}{1 - p_i}\right) = \beta'_{x_i} = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \beta_3 x_{i3} + \ldots + \beta_{20} x_{i20} \quad (3)$$

For $i = 1, \ldots, n$. In order to estimate the parameters of interest, we adopt the maximum likelihood method.

According to [38], the coefficient of the logistic model result can be written in terms of the odds and log of the odds ratio. The regression coefficient obtained by performing a logistic regression is the estimated increase in the log odds of the dependent variable per unit increase in the value of the independent variable of interest. Given that log odds are difficult to interpret on their own, we convert the log odds to normal odds (OR) using the exponential function to facilitate the interpretation of the estimated coefficients. OR are defined as the ratio of p_i and $1 - p_i$. p_i refers to the probability that the teacher will be using ICT frequently or always in the class. $1 - p_i$ refers to the probability that the teacher will not use ICT or will use it only occasionally. The formula of the probability that a teacher will never or only occasionally use ICT in the class is:

$$1 - p_i = \frac{1}{1 + exp\{\beta' x_i\}} \quad (4)$$

Then, the odds ratio can be written as the ratio between Equations (1) and (4):

$$\frac{p_i}{1 - p_i} = \frac{1 + exp\{\beta' x_i\}}{1 + exp\{-\beta' x_i\}} = exp\{\beta' x_i\} \quad (5)$$

An odds ratio greater than 1 describes a positive relationship indicating that as the independent variable value increases, the odds of using ICT frequently in classes increase. On the contrary, an odds ratio less than 1 describes a negative relationship. Specifically, the estimated odds ratio represents the factor that multiplies the probability of using ICT frequently in classes for the corresponding independent variable when it increases by one unit on the scale of the variable and the remaining variables stay constant.

Once the estimation of the main models had been carried out, a series of post-estimation tests were performed. First, as previously explained when discussing the assumptions required in a logit, the link test and Box–Tidwell test were performed. Additionally, we used the Hosmer and Lemeshow test [39] to evaluate whether the logistic regression model was well calibrated. As can be seen in Table A10 in the Appendix A, at a confidence level of 95%, the output of the test represents that the adjusted model is well calibrated (p-values > 0.05) which shows that the model adequately fits the whole set of observations.

Likewise, we analysed the sensitivity and specificity by creating an ROC curve and obtaining the value of the area under curve (AUC), as shown in Figures A1–A3 in the Appendix A. In relation to the AUC, it takes values from 0 to 1, where a value of 0 indicates a perfectly inaccurate test and a value of 1 reflects a perfectly accurate test. In our case, as the figures in the Appendix A show, the value of the area under curve (AUC) is around 0.6–0.7 in the three models, values that are considered acceptable according to [39]. Likewise, the ROC curves are above the diagonal line and can therefore be considered to have a reasonable discriminating ability.

4. Results

Table 1 shows the results of the multilevel logistic models for the association between student, teacher, and school characteristics and the frequency of ICT used to carry out projects or do exercises in class. As explained in Section 3.4, the results are expressed in terms of odds ratios (OR) and the interpretation of OR differs according to the type of variable analysed [40]. For categorical explanatory variables, the OR is with respect to a reference category. For example, the OR for teacher gender refers to the odds of using ICT frequently in class in women versus men. If a categorical variable has more than two categories (e.g., public, semiprivate, or private school), then separate ORs are calculated for each of the categories relative to the reference category (semiprivate vs. public; private vs. public). For continuous predictors (e.g., teacher's year of birth), the OR represents the increase or decrease in odds of the outcome of interest (using ICT frequently or always in the class) with every one unit increase in the explanatory continuous variable. In this regard, it is important to point out that the ordinal variables (e.g., teacher's motivation or disturbance in class) can be entered in the logistic models as continuous variables or as categorial variables using dummy indicator variables for each level [41]. Treating an ordinal predictor as a continuous variable implies assuming that a simple linear or polynomial function can adequately explain the relationship between the response and the predictor. However, treating an ordinal predictor as a categorical variable, we do not assume a linear or proportional effect along the scale, but in turn more data are required to obtain viable results. Considering the characteristics of our data (low number of observations in some categories of various ordinal variables) we included as the main model (Table 1) the estimates in which the ordinal predictors have been introduced as continuous predictors. However, we also performed the estimations including these variables as categorical predictors (Table A11 in Appendix A) to complement our results, given that in those cases in which we find a sufficiently large number of observations in each of the response categories, it is appropriate to look at the results obtained in these regressions.

Table 1. Determinants of ICT use in classes (multilevel logistic models).

	(1)	(2)	(3)
Variables	**3rd Year Primary Education**	**6th Year Primary Education**	**4th Year Secondary Education**
ICT use at home (Student)	3.234 ***	9.582 **	4.765 **
	(1.423)	(9.331)	(3.289)
ICT training (Teacher)	1.302 ***	1.787 ***	1.242 ***

	(0.101)	(0.131)	(0.0908)
Lack of tech. devices (Director)	0.787 ***	0.808 ***	0.792 ***
	(0.0536)	(0.0567)	(0.0507)
Books at home (Student)	0.981	1.026	0.981
	(0.0392)	(0.0370)	(0.0368)
Immigrant (Student)	0.526	0.355	0.440 *
	(0.233)	(0.287)	(0.219)
Female (Student)	0.660	1.339	1.090
	(0.241)	(0.495)	(0.293)
Repeater (Student)	N.A.	0.340 **	0.976
		(0.161)	(0.394)
Female (Teacher)	0.955	1.056	0.962
	(0.0927)	(0.0856)	(0.0745)
Year of birth (Teacher)	1.002	1.004	1.002
	(0.00420)	(0.00371)	(0.00391)
Motivation (Teacher)	1.408 ***	1.195 ***	1.099 *
	(0.0770)	(0.0594)	(0.0555)
Time dedication (Teacher)	1.810 ***	0.953	1.334 **
	(0.367)	(0.199)	(0.175)
Disturbance in class (Teacher)	0.892 ***	0.967	0.898 ***
	(0.0364)	(0.0371)	(0.0372)
Class Size (Student)	1.004	0.991	0.987
	(0.0164)	(0.0158)	(0.0102)
School ownership (semi-private school)	0.854	0.915	1.122
	(0.114)	(0.125)	(0.139)
School ownership (private school)	1.886 **	1.625 *	1.064
	(0.490)	(0.432)	(0.224)
Lack of teacher training (Director)	0.955	0.895	0.788 ***
	(0.0787)	(0.0750)	(0.0622)
Lack of autonomy (Director)	0.973	1.264 ***	1.183 **
	(0.0750)	(0.0991)	(0.0790)
Subject (Spanish)	0.991	0.757 ***	4.130 ***
	(0.0803)	(0.0677)	(0.407)
Subject (English)	1.877 ***	0.837 *	5.659 ***
	(0.159)	(0.0762)	(0.580)
Subject (Science and Tec./Social and Civic)	N.A.	0.495 ***	5.234 ***
		(0.0443)	(0.536)
Constant	0.00614	0.00008	0.00236
	(0.0513)	(0.000642)	(0.0183)
Observations	5366	6785	4773
Number of schools	1105	1083	656

* Standard error in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$; ** Results are expressed in odd ratios.

If we focus on analysing first the variables classified as variables of interest in this research—those that potentially seem to have a stronger relationship with the use of ICT in the classes—the results confirm that in all the educational levels the three of them are statistically significant for explaining the probability of using ICT in classes for educational purposes. Specifically, the results show that the most relevant factor is the students' use of ICT at home. In this sense, it is observed that the greater the number of students in classes who use ICT frequently, every day, or almost every day at home, the greater the probability that the teacher decides to use these tools frequently or always in his or her class at all the educational levels analysed (odds ratio = 2.234; odds ratio = 9.582; odds ratio = 4.765). With respect to teacher characteristics, the results show that odds are 1.302 (3rd year of primary education), 1.787 (6th year of primary education), and 1.242 (4th year of secondary education) times higher that a teacher who has received ICT training will use ICT in his or her classes compared to a teacher who has not received ICT training. These findings are in line with [13,17,19] and suggest that teachers trained in the use of ICT are more likely to use ICT in their classes. In this sense, we consider that these results highlight the need to implement training programs in the use of ICTs in order to increase their frequency and quality of use in schools, as has also been suggested in previous literature [1–6]. Finally, in relation to the availability of ICT resources in school, the results show that this is also a relevant factor, and that the greater the lack of ICT resources in the school, the less likely teachers are to use ICT frequently in their classes. Specifically, the results show that with every one unit increase in the value of the variable "Lack of technological devices", there is around a 20% lower likelihood of teachers using ICT in the class. This result is in line with [21,22].

The results also show the relevance of other variables included in the regressions, which, although not directly related to ICTs, seem to clearly influence the teachers' frequency of use of ICT. In this sense, at the teacher level a very relevant result is the positive association between the motivation of teachers (approximated by their satisfaction with the profession) and the probability of using ICT in the class. Our regressions suggest that with every one unit increase in the value of the variable "Motivation", the odds are around 40% higher in the 3rd year of primary education and around 20% higher in the 6th year of primary education that teachers will use ICT in their classes. In the 4th year of secondary education, the odds ratio obtained when the variable "Motivation" is introduced as a continuous predictor is only statistically significant at the 0.10 significance level, and in this research we consider 0.05 as the threshold to discriminate significant from non-significant results. However, if we complement these results with those obtained in Table A11 when this variable is introduced as a categorical variable, we observe that at this educational level there is a clear difference between the probability of ICT use by teachers who answer that they are totally satisfied with their profession (maximum level of satisfaction) and those who answer that they are not at all satisfied with their work (reference category) since the odds ratios are statistically significant at the 0.05 significance level. Specifically, the results suggest that the teachers who strongly agree with the satisfaction statement are around 80% more likely to use ICT frequently in classes than those who are not at all in agreement with the statement. Based on these results, it can be concluded that motivated teachers are more likely to use ICT in classes in all the educational levels, as also suggested by [14].

With respect to other teacher characteristics, we find that the gender and age of the teacher do not affect the probability of ICT use based on our results. However, we do observe that teachers who work full time (compared to those who work part time) are more likely to use ICT in their classes in the 3rd year of primary education (odds 1.810) and 4th year of secondary education (odds = 1.334). Another particularly interesting result is that, in the 3rd year of primary education and 4th year of secondary education, we find that with every one unit increase in the value of the variable "Disturbance in class" the odds are around a 10% lower that teachers will use ICT in their classes. In the case of the 6th year of primary education, although the results in Table 1 reflect an odds ratio that is not statistically significant, we believe it is interesting to complement the interpretation of this result with the results in Table A11. In this sense, Table A11 shows that when the variable "Disturbance in class" is introduced as a categorical predictor, it is observed that the teachers who indicate that disturbance is a moderate problem are around 30% less likely to use ICT frequently in classes than those who indicate that disturbance is not a problem. It seems, therefore, that teachers who teach in classes with good student behaviour are more likely to use ICT frequently as a teaching method in all the educational levels.

As for other variables included that have to do with the characteristics of the students taught by each teacher, we find that the greater the number of repeater students in the classes, the lower the probability that the teacher decides to use ICT in his or her class in the 6th year of primary education (odds ratio = 0.340). However, for the rest of the student-level variables included in our logistic regressions (gender, immigration status, and number of books at home)—leaving aside the use of ICTs at home by students—the odds ratios estimated are not statistically significant. Class size also shows no statistical significance.

Regarding the school climate, we find that the ownership of the school seems to be a determining factor in the use of ICT in classes only in the 3rd year of primary education. Specifically, for this educational level we find that private schools—as compared to public schools—are more likely to have teachers who use ICT in their classes. In the rest of the educational levels and types of schools, ownership is not a determining factor. In relation to the characteristics of the educational centre, we also find that in the 4th year of secondary education, with every one unit increase in the value of the variable "Lack of teacher training", the odds are around 20% lower that teachers will use ICT in their classes. However, this relationship is not observed in the rest of the educational levels. On the other hand, the lack of decision-making autonomy at the school level seems to be positively related to the likelihood of implementing ICT in classes in the 6th year of primary education (odds = 1.264) and 4th year of secondary education (odds = 1.183).

Finally, with regard to the subjects taught, the results clearly show that the probability of using ICT differs by subject. In this sense, in the 3rd year of primary education it is observed that odds are 1.877 times higher that a teacher who teaches English will use ICT in his or her classes compared to a teacher who teaches mathematics (reference category), while neither higher nor lower odds are observed in the case of Spanish compared to mathematics. In the 6th year of primary education, the results indicate that if the teacher teaches Spanish or Science and Technology, there is around a 25% and 50%, respectively, lower likelihood that he or she uses ICT in the class as compared to a mathematics teacher. Finally, in the 4th year of secondary education, the results suggest that odds are 4.130 (in Spanish), 5.659 (in English), and 5.234 (in social and civic competence) times higher that a teacher who teaches Spanish, English, or social and civic competence will use ICT in his or her classes compared to a teacher who teaches mathematics.

5. Conclusions

The results of the multilevel logistic regressions show that teachers' decisions to implement ICT are motivated by a series of personal characteristics, those of their students, and of the educational institution where they teach. These characteristics are mostly shared at the three educational levels analysed: the 3rd year of primary education, 6th year of primary education, and 4th year of secondary education. In this final section, we reflect on the most relevant findings of this research, which represent a novel and updated contribution to the previously scarce literature in this area.

In relation to the characteristics of the students in the classes, we find that certain students' individual characteristics are relevant to explain the frequency of use of ICT as a teaching tool. In this sense, if teachers have classes with students that frequently, every day, or almost every day use ICT at home, they are more likely to use ICT in the class than if their students never, almost never, or only occasionally use ICT at home. This finding indicates that students' familiarization with ICT matters for teachers, and that they are more likely to introduce ICT in classes if students are familiar with these tools through their regular use at home. In this sense, it is to be expected, for example, that if teachers have students who are good at surfing the Internet, they might be more likely to have them carry out an exercise by searching for information on the Internet. Or, for example, if because they use ICT more frequently at home, students are able to type at high speed on a computer document, teachers might be more likely to send computer-based assignments. In addition to increasing the likelihood of ICT use in the class, in previous literature the frequency of ICT use by children and adolescents at home has also been positively related to academic performance [42,43]. Although, as evidenced by the descriptive statistics in Section 3.2, the majority of students surveyed reported frequent use of ICTs at home, we still found some students at all levels of education who reported not using these technologies at home. Considering this, and in order to increase the presence of ICTs in schools to take advantage of all their potential benefits, we believe that it would be advisable for governments to develop public policies aimed at providing technological resources to households who cannot afford to buy them of have access to them. Of course, we consider it important that the increased availability of ICT resources in the home is complemented by measures to ensure that children and adolescents make good use of these tools.

Student behaviour in classes also appears to be a determining factor in the use of ICT in classes. According to our estimations in all the educational levels, teachers who report having a problem with disturbance in their class are less likely to use ICT in classes than those who indicate not having problems at all with disruptive behaviours. This result seems to indicate that teachers find problems in applying new technologies in classes when they find an environment of bad behaviour, and that they are more likely to innovate with new technologies if students are calm and their class is respectful. While it is difficult to make recommendations to address the problem of bad behaviour, this result highlights yet another negative consequence of a disruptive environment. In this regard, we believe that schools should pay special attention to classes' environments and distribute students among different class groups to ensure, as far as possible, a positive class environment. Based on the results of this research, this would lead to a greater use of ICT and thus a potential improvement in academic performance.

Regarding the teachers' characteristics, we find that the teachers who had received ICT training in the last 12 months were more likely to use ICT frequently in their classes in the three educational levels evaluated in this research. In this sense, when designing the research, we thought that although it seemed logical that the teacher's level of ICT training would affect the frequency of use, perhaps it was not such a key aspect given that, in general terms, an advanced level of ICTs use is not necessary to be able to implement them in the classroom. In other words, we did not know to what extent ICT training (attending courses) was going to be relevant when it came to making decisions, and therefore whether or not it made sense to invest resources in carrying out courses of this type. However, the empirical evidence in this research highlights the importance of implementing ICT training programs for teachers to encourage greater and better use of ICT and to take advantage of the potential benefits of these tools. In this sense, our recommendations are along the lines of promoting ICT training for teachers from the Public Administration, but also from the educational centres themselves with internal training and group dynamics among teachers to compare experiences in the use of ICT.

We also observe that teachers' motivation seems to be a key aspect in explaining the implementation of ICT in classes in all the educational levels. Higher levels of teachers' motivation increase the probability of using ICTs in classes. This finding highlights the relevance of teacher motivation in promoting innovation (such as using ICT) in classes, and shows how important it is to have teachers who are highly satisfied with their job. In this sense, our recommendations go in the direction of ensuring that the teaching profession is valued by society as a whole and that teachers have the necessary support from the Public Administrations and schools to solve their problems and foster their satisfaction with their job and profession.

Finally, in relation to the school characteristics, we find that the greater the lack of ICT resources in the school, the less likely teachers are to use ICT. In this regard, when designing this research, we thought it was predictable that ICT availability would be found to be a key factor, but on the other hand it might not, since perhaps the use of ICT was not so dependent on the number of resources as on other factors. For example, one of our hypotheses was that there were other factors (personal characteristics of the teacher or the classroom) that affected the decision to use ICT more than the availability of resources, so that paradoxically, in a school with more computers, ICT was used less than, for example, in a school with only one computer per classroom but a highly motivated teaching staff. Nevertheless, the results show that the decision to use ICTs by teachers is influenced by the availability of ICTs in schools. In this regard, the descriptive statistics showed that only 39% of principals stated that they considered that there was no problem with a lack digital resources in their school. This shows that there is ample room for improvement in this regard, and that public policies are needed to improve the availability of ICT resources in schools.

Having reflected on and developed recommendations based on the main results of this research, we believe it is also important to contextualize the results in the current context. In this sense, the health crisis caused by COVID-19 and the closure of schools in March 2020 was a turning point in the use of ICT in education. Specifically, the closure of schools forced teachers to use ICT to teach online and to familiarise themselves with the use of these tools. We consider that the forced learning that teachers faced in March 2020 can be expected to have boosted the level of teacher ICT skills and can therefore be interpreted as an increase in ICT training for teachers. Considering the results of this research, this increased level of ICT training could translate into greater use of ICT in classes now and in the future. Indeed, the recent study by [44] shows that, after the home confinement and return to face-to-face classes, the percentage of Spanish teachers surveyed who reported using ICT in classes on a daily basis increased from 58% to 83%. This evidence suggests that the pandemic has prompted an educational reform in terms of ICT use. In this context of the increased role of ICT in schools, all the recommendations made in this research should be considered to take advantage of the improvement of teacher training in ICT and to develop educational policies or carry out actions to promote ICT use, also based on the other statistically significant factors in the multilevel regressions of this research.

We also consider it important to reflect on future lines of research based on the results of this research. In this sense, firstly, and considering the consequences of the pandemic described above, it would be particularly relevant to replicate the analyses of this research when national and international databases are published with information on ICT use in education after the home-confinement of students. Additionally, we consider that this research topic needs to be complemented with qualitative research that provides the detailed information necessary to understand the empirical evidence obtained in this research. For example, finding out the impressions, opinions, and perspectives of students, teachers, and school principals in relation to ICTs would allow us to gain a deeper understanding of why the factors found in this research lead teachers to use ICT more- or less frequently, and thus allow us to make more concrete recommendations. In this sense, a possible line of future research would be to accompany the statistical analyses of this research with information obtained from qualitative questionnaires.

As regards the external validity of the results of this research, the decision to focus the analysis on the Community of Madrid (Spain) was based on knowledge of the country's educational system, the availability of data, and on the commitment to the use of ICT for educational purposes made by the Public Administrations in the last decade. For the latter reason, it is especially relevant to know the factors that influence teachers' decisions to use ICT in their classes in order to be able to adequately guide public policies and measures aimed at promoting the use of ICT in the educational sphere. Nevertheless, the results presented in this research may be useful for other countries, in the absence of being corroborated with their own research. In this sense, it should be noted that ICT is a global phenomenon that is bursting into society and the educational system in all countries, so it is to be expected that the conclusions reached in this thesis can also be extrapolated to other geographical areas. However, another future line of research would be to replicate these analyses with data from other geographical areas.

By way of general conclusion, all the results obtained in this research allow us to draw a typical profile of teachers who are more likely to use ICT frequently to carry out projects or do exercises in class. Based on our results, a motivated teacher (satisfied with the profession) who has received ICT training and teaches in a calm and respectful class, in a school which does not have a lack of digital devices, and with students who frequently use ICT at home, has a high predisposition to use ICT in his or her classes. The configuration of this profile is relevant as it can help guide educational policy measures aimed at increasing the presence of ICT in classes in order to take advantage of its potential benefits. In parallel to the recommendations for Public Administrations and schools suggested in this paper, we believe it is necessary to continue research on the use of ICT in schools, especially considering the rapid pace at which these technologies are evolving. Based on scientific evidence, policies aimed at increasing the use of ICT in classes should be accompanied by a good program of recommendations on their use that will allow teachers to take full advantage of these tools and consequently improve the academic performance of their students.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Definition of dependent and independent variables.

DEPENDENT VARIABLE	
Teacher questionnaire	
ICT use in class	0 = never, almost never or occasionally 1 = frequently, every day or almost everyday
INDEPENDENT VARIABLES	
Student questionnaire	
Female	0 = male 1 = female
Immigrant	0 = student was born in Spain. 1 = student was not born in Spain.
Repeater	0 = never repeated 1 = repeated once or more

Books at home	0 = from 0 to 10 1 = from 11 to 50 2 = from 51 to 100 3 = from 101 to 200 4 = more than 200
Frequency of computer or tablet use at home	0 = never, almost never or occasionally 1 = frequently, every day or almost everyday
Class size	"Number of students in class"
Teacher questionnaire	
Female	0 = male 1 = female
Year of birth	Year number
School ownership	0 = public school 1 = semiprivate school 2 = private school
Time dedication	0 = part time 1 = full time
ICT training in the last 12 months	0 = No 1 = Yes
Disturbance of order in class	0 = not a problem 1 = slight problem 2 = moderate problem 3 = serious problem
Satisfaction with the profession (motivation)	Degree of agreement/disagreement with the statement: "If I could decide again, I would continue to choose this job". 0 = nothing in agreement 1 = little bit of agreement 2 = quite agree 3 = strongly agree
Subject taught	3rd year of primary education: 1 = Mathematics 2 = Spanish 3 = English 6th year of primary education: 1 = Mathematics 2 = Spanish 3 = English 4 = Science and technology 4th year of secondary education: 1 = Academic mathematics 2 = Spanish 3 = English 4 = Social and Civic
School questionnaire	
Lack of a teacher training plan	0 = absolutely 1 = very little 2 = to some extent 3 = a lot
Lack of autonomy to decide	0 = absolutely 1 = very little 2 = to some extent 3 = a lot
Lack of technological devices for teaching	0 = absolutely 1 = very little 2 = to some extent 3 = a lot

Table A2. Descriptive statistics (3rd year of primary education).

Variable	Obs.	%/Mean *	Std. Dev.	Min./Max.	% Missing
Student and family Questionnaire					
Female	69,902	0: 48.58 1: 51.42	0.50	0/1	0.55
Immigrant	34,623	0: 95.87 1: 4.13	0.20	0/1	50.74
Books at home	34,916	0: 5.77 1: 24.07 2: 27.35 3: 19.72 4: 23.10	1.22	0/4	50.62
Computer/tablet use at home	34,709	0: 5.16 1: 94.84	0.22	0/1	50.32
Class size	69,977	24.54	2.95	1/36	0.44
Teacher Questionnaire					
ICT use in class	6055	0: 47.63 1: 52.37	0.450	0/1	4.04
Female	6297	0: 22.06 1: 77.94	0.42	0/1	0.21
Year of birth	6287	1977.27	9.88	1948/1997	0.36
School ownership	6263	0: 58.74 1: 34.15 2: 7.11	0.63	0/2	0.74
Time dedication	6291	0: 4.48 1: 95.52	0.21	0/1	0.30
ICT training	4964	0: 47.63 1: 52.37	0.50	0/1	21.33
Disturbance of order in class	6124	0: 23.64 1: 35.58 2: 26.55 3: 14.22	0.99	0/3	2.95
Satisfaction (motivation)	6261	0: 2.80 1: 10.32 2: 52.13 3: 34.75	0.73	0/3	0.78
Director Questionnaire					
Lack teacher training	1228	0: 29.97 1: 44.38 2: 22.96 3: 2.69	0.80	0/3	1.76
Lack autonomy	1227	0: 26.30 1: 41.08 2: 28.36 3: 4.24	0.84	0/3	1.84
Lack technological devices	1234	0: 39.30 1: 33.31 2: 21.23 3: 6.16	0.92	0/3	1.28

* In the case of categorical variables, the relative frequencies are presented, while for continuous variables the mean is used.

Table A3. Descriptive statistics (6th year of primary education).

Variable	Obs.	%/Mean *	Std. Dev.	Min./Max.	% Missing
Student and family Questionnaire					
Female	69,330	0: 48.41 1: 51.59	0.50	0/1	0.50
Immigrant	28,969	0: 95.46 1: 4.54	0.21	0/1	58,42
Repeater	46,548	0: 87.30 1: 12.70	0.33	0/1	33.19
Books at home	29,200	0: 4.27 1: 20.64 2: 26.10 3: 20.45 4: 28.53	1.22	0/4	58.09
Computer/tablet use at home	29,078	0: 3.37 1: 96.63	0.18	0/1	58.27
Class size	69,343	24.46	3.11	1/40	0.48
Teacher Questionnaire					
ICT use in class	7588	0: 35.04 1: 64.96	0.48	0/1	4.16
Female	7887	0: 30.02 1: 69.98	0.46	0/1	0.38
Year of birth	7866	1975.64	10.19	1950/1996	0.64
School ownership	7815	0: 59.01 1: 33.04 2: 7.95	0.64	0/2	1.29
Time dedication	7880	0: 3.49 1: 96.51	0.18	0/1	0.47
ICT training	6485	0: 44.92 1: 55.08	0.50	0/1	18.09
Disturbance of order in class	7656	0: 27.13 1: 35.96 2: 23.26 3: 13.65	0.99	0/3	3.30
Satisfaction (motivation)	7854	0: 3.62 1: 10.13 2: 51.67 3. 34.58	0.75	0/3	0.80
Director Questionnaire					
Lack teacher training	1215	0: 29.88 1: 44.53 2: 22.88 3: 2.72	0.80	0/3	1.86
Lack autonomy	1214	0: 26.28 1: 41.02 2: 28.42 3: 4.28	0.84	0/3	1.94
Lack technological devices	1221	0: 39.31 1: 33.25 2: 21.21 3: 6.22	0.92	0/3	1.37

* In the case of categorical variables, the relative frequencies are presented, while for continuous variables the mean is used.

Table A4. Descriptive statistics (4th year of secondary education).

Variable	Obs.	%/Mean *	Std. Dev.	Min./Max.	% Missing
Student Questionnaire					
Female	62,150	0: 50.04 1: 49.96	0.50	0/1	1.32
Immigrant	34,457	0: 87.93 1: 12.07	0.33	0/1	45.29
Repeater	30,848	0: 84.94 1: 15.06	0.50	0/1	51.02
Books at home	34,548	0: 6.88 1: 22.19 2: 25.09 3: 21.21 4: 24.63	1.26	0/4	45.14
Computer/tablet use at home	34,355	0: 7.28 1: 92.72	0.26	0/1	45.45
Class size	62,166	27.35	4.07	1/48	1.29
Teacher Questionnaire					
ICT use in class	5543	0: 43.51 1: 56.49	0.50	0/1	0.00
Female	5753	0: 35.49 1: 64.51	0.48	0/1	0.38
Year of birth	5739	1973.86	9.49	1947/1997	0.62
School ownership	5730	0: 49.95 1: 40.19 2: 9.86	0.66	0/2	0.78
Time dedication	5755	0: 9.04 1: 90.96	0.29	0/1	0.35
ICT training	4605	0: 45.45 1: 54.55	0.50	0/1	20.26
Disturbance of order in class	5603	0: 15.92 1: 39.82 2: 30.64 3: 13.62	0.91	0/3	2.98
Satisfaction (motivation)	5740	0: 2.16 1: 10.91 2: 49.97 3: 36.97	0.72	0/3	0.61
Director Questionnaire					
Lack teacher training	717	0: 32.22 1: 45.04 2: 21.34 3: 1.39	0.77	0/3	3.11
Lack autonomy	718	0: 27.58 1: 35.10 2: 28.55 3: 8.77	0.94	0/3	2.97
Lack technological devices	722	0: 39.89 1: 35.32 2: 19.11 3: 5.68	0.90	0/3	2.43

* In the case of categorical variables, the relative frequencies are presented, while for continuous variables the mean is used.

Table A5. Determinants of ICT use in classes (multilevel probit models).

	(1)	(2)	(3)
Variables	**3rd Year Primary Education**	**6th Year Primary Education**	**4th Year Secondary Education**
ICT use at home (Student)	0.684 ***	1.323 **	0.937 **
	(0.260)	(0.571)	(0.412)
ICT training (Teacher)	0.157 ***	0.334 ***	0.130 ***
	(0.0460)	(0.0430)	(0.0436)
Lack of tech. devices (Director)	−0.141 ***	−0.126 ***	−0.140 ***
	(0.0403)	(0.0411)	(0.0382)
Books at home (Student)	−0.0112	0.0158	−0.0126
	(0.0236)	(0.0212)	(0.0224)
Immigrant (Student)	−0.382	−0.586	−0.490 *
	(0.264)	(0.474)	(0.297)
Female (Student)	−0.241	0.163	0.0489
	(0.217)	(0.216)	(0.160)
Repeater (Student)		−0.637 **	−0.0287
		(0.277)	(0.240)
Female (Teacher)	−0.0280	0.0352	−0.0237
	(0.0572)	(0.0475)	(0.0461)
Year of birth (Teacher)	0.00100	0.00243	0.00126
	(0.00248)	(0.00216)	(0.00233)
Motivation (Teacher)	0.202 ***	0.106 ***	0.0557 *
	(0.0322)	(0.0291)	(0.0301)
Time dedication (Teacher)	0.348 ***	−0.0278	0.173 **
	(0.120)	(0.123)	(0.0782)
Disturbance in class (Teacher)	−0.0670 ***	−0.0181	−0.0630 **
	(0.0241)	(0.0225)	(0.0247)
Class Size (Student)	0.00239	−0.00562	−0.00782
	(0.00966)	(0.00933)	(0.00618)
School ownership (semi-private school)	−0.0985	−0.0482	0.0722
	(0.0788)	(0.0796)	(0.0737)
School ownership (private school)	0.379 **	0.289 *	0.0429
	(0.154)	(0.155)	(0.125)
Lack of teacher training (Director)	−0.0287	−0.0641	−0.143 ***
	(0.0489)	(0.0491)	(0.0470)
Lack of autonomy (Director)	−0.0162	0.138 ***	0.101 **
	(0.0457)	(0.0459)	(0.0398)
Subject (Spanish)	−0.00368	−0.161 ***	0.850 ***
	(0.0482)	(0.0524)	(0.0582)
Subject (English)	0.369 ***	−0.101 *	1.038 ***
	(0.0500)	(0.0532)	(0.0600)
Subject (Science and Tec./Social and Civic)		−0.411 ***	0.993 ***
		(0.0523)	(0.0602)
Constant	−2.825	−5.492	−3.643
	(4.942)	(4.331)	(4.635)
Observations	5366	6785	4773
Number of schools	1105	1083	656

* Standard error in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A6. Determinants of ICT use in classes (complete case analysis).

	(1)	(2)	(3)
Variables	**3rd Year Primary Education**	**6th Year Primary Education**	**4th Year Secondary Education**
ICT use at home (Student)	2.173 **	4.766 **	5.390 **
	(1.107)	(5.268)	(4.130)
ICT training (Teacher)	1.597 ***	2.232 ***	1.346 ***
	(0.152)	(0.202)	(0.113)
Lack of tech. devices (Director)	0.791 ***	0.822 **	0.795 ***
	(0.0611)	(0.0662)	(0.0551)
Books at home (Student)	1.013	1.044	0.955
	(0.0467)	(0.0433)	(0.0401)
Immigrant (Student)	0.813	0.390	0.425
	(0.418)	(0.369)	(0.235)
Female (Student)	0.747	1.080	1.040
	(0.314)	(0.493)	(0.310)
Repeater (Student)		0.365 *	0.967
		(0.199)	(0.430)
Female (Teacher)	0.910	1.082	0.932
	(0.102)	(0.103)	(0.0813)
Year of birth (Teacher)	1.004	1.002	1.006
	(0.00496)	(0.00433)	(0.00441)
Motivation (Teacher)	1.407 ***	1.314 ***	1.105 *
	(0.0903)	(0.0758)	(0.0631)
Time dedication (Teacher)	1.887 ***	0.864	1.379 **
	(0.441)	(0.209)	(0.200)
Disturbance in class (Teacher)	0.877 ***	0.939	0.891 **
	(0.0417)	(0.0424)	(0.0415)
Class Size (Student)	1.013	0.993	0.991
	(0.0188)	(0.0187)	(0.0114)
School ownership (semi-private school)	0.929	0.996	1.294 *
	(0.140)	(0.157)	(0.175)
School ownership (private school)	1.860 **	1.716 *	1.113
	(0.537)	(0.526)	(0.252)
Lack of teacher training (Director)	1.017	0.917	0.738 ***
	(0.0950)	(0.0887)	(0.0627)
Lack of autonomy (Director)	0.957	1.278 ***	1.244 ***
	(0.0831)	(0.115)	(0.0894)
Subject (Spanish)	0.975	0.693 ***	4.022 ***
	(0.0913)	(0.0717)	(0.448)
Subject (English)	1.907 ***	0.897	5.233 ***
	(0.190)	(0.0947)	(0.595)
Subject (Science and Tec./Social and Civic)		0.444 ***	5.220 ***
		(0.0460)	(0.614)
Constant	0.000175	0.0219	0.000
	(0.00173)	(0.190)	(0.000)
Observations	4244	5557	3818
Number of schools	1039	1030	652

* Standard error in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$; ** Results are expressed in odd ratios.

Table A7. Determinants of ICT use in classes (complete case analysis with % missing < 5%).

	(1)	**(2)**	**(3)**
Variables	**3rd Year Primary Education**	**6th Year Primary Education**	**4th Year Secondary Education**
Lack of tech. devices (Director)	0.778 ***	0.792 ***	0.782 ***
	(0.0528)	(0.0566)	(0.0506)
Female (Student)	0.740	1.251	1.088
	(0.267)	(0.463)	(0.292)
Female (Teacher)	0.945	1.007	0.967
	0.740	1.251	1.088
Year of birth (Teacher)	1.002	1.005	1.002
	(0.00418)	(0.00370)	(0.00391)
Motivation (Teacher)	1.379 ***	1.180 ***	1.103 *
	(0.0748)	(0.0585)	(0.0557)
Time dedication (Teacher)	1.871 ***	1.029	1.387 **
	(0.377)	(0.214)	(0.182)
Disturbance in class (Teacher)	0.890 ***	0.956	0.890 ***
	(0.0360)	(0.0365)	(0.0367)
Class Size (Student)	1.004	1.004	0.989
	(0.0158)	(0.0158)	(0.0102)
School ownership (semi-private school)	0.898	0.993	1.169
	(0.118)	(0.136)	(0.144)
School ownership (private school)	1.952 ***	2.003 ***	1.125
	(0.495)	(0.529)	(0.233)
Lack of teacher training (Director)	0.939	0.876	0.778 ***
	(0.0768)	(0.0747)	(0.0619)
Lack of autonomy (Director)	0.966	1.268 ***	1.184 **
	(0.0742)	(0.101)	(0.0796)
Subject (Spanish)	0.995	0.755 ***	4.057 ***
	(0.0801)	(0.0674)	(0.399)
Subject (English)	1.876 ***	0.837 *	5.592 ***
	(0.158)	(0.0759)	(0.572)
Subject (Science and Tec./Social and Civic)		0.503 ***	5.188 ***
		(0.0448)	(0.530)
Constant	0.0101	0.000241	0.00444
	(0.0835)	(0.00177)	(0.0343)
Observations	5401	6785	4773
Number of schools	1114	1083	656

* Standard error in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$; ** Results are expressed in odd ratios.

Table A8. Collinearity Test Results (3rd year of Primary Education; 6th year of Primary Education; and 4th year of Secondary Education).

	Variance Inflation Factors		
Variables	**3rd Year Primary Education**	**6th Year Primary Education**	**4th Year Secondary Education**
ICT use at home (Student)	1.13	1.11	1.18
ICT training (Teacher)	1.02	1.02	1.02
Lack of tech. devices (Director)	1.11	1.12	1.14
Books at home (Student)	1.24	1.10	1.23
Immigrant (Student)	1.12	1.15	1.35
Female (Student)	1.02	1.02	1.03
Repeater (Student)	N.A.	1.25	1.53
Female (Teacher)	1.04	1.03	1.02
Year of birth (Teacher)	1.07	1.02	1.04
Motivation (Teacher)	1.01	1.01	1.02
Time dedication (Teacher)	1.06	1.04	1.05
Disturbance in class (Teacher)	1.02	1.03	1.06
Class Size (Student)	1.05	1.10	1.21
School ownership	1.31	1.29	1.56
Lack of teacher training (Director)	1.24	1.19	1.24
Lack of autonomy (Director)	1.18	1.15	1.29
Subject	1.03	1.00	1.01
Condition Number	1.93	1.93	2.36

Table A9. Link Test Results.

	(1)	(2)	(3)
ICT Use	**3rd Year Primary Education**	**6th Year Primary Education**	**4th Year Secondary Education**
_hat	0.174 ***	0.188 ***	0.193 ***
	(0.013)	(0.023)	(0.008)
_hatsq	0.021	−0.005	−0.000
	(0.015)	(0.119)	(0.098)
_cons	0.487 ***	0.482 ***	0.498 ***
	(0.008)	(0.118)	(0.010)

* Standard error in parentheses. *** $p < 0.01$.

Table A10. Hosmer and Lemeshow Test Results (3rd year of Primary Education; 6th year of Primary Education; and 4th year of Secondary Education).

Hosmer and Lemeshow Test		
	Chi-Square	**Sig.**
3rd Primary Education	10.64	0.229
6th Primary Education	12.73	0.121
4th Secondary Education	13.27	0.115

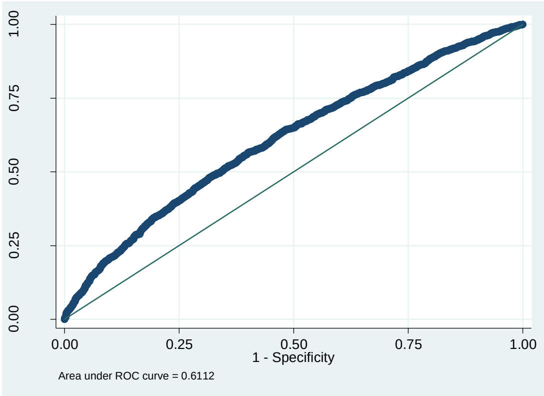

Figure A1. ROC curve (model for 3rd year of primary education).

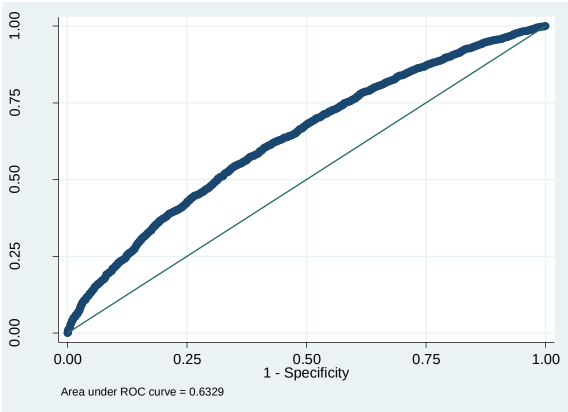

Figure A2. ROC curve (model for 6th year of primary education).

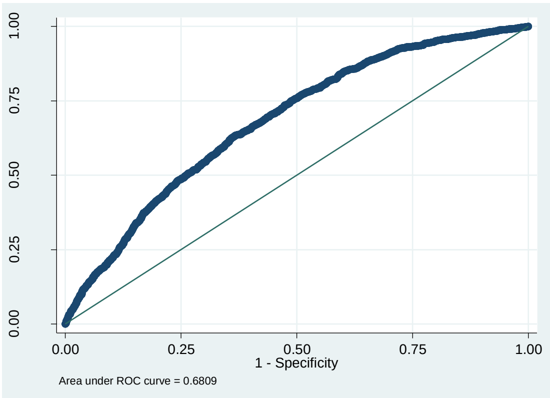

Figure A3. ROC curve (model for 4th year of secondary education).

Table A11. Determinants of ICT use in classes (multilevel logistic models with ordinal variables entered as categorical variables).

	(1)	(2)	(3)
Variables	**3rd Year Primary Education**	**6th Year Primary Education**	**4th Year Secondary Education**
ICT use at home (Student)	3.155 **	10.63 **	4.809 **
	(1.416)	(10.62)	(3.318)
ICT training (Teacher)	1.294 ***	1.817 ***	1.245 ***
	(0.101)	(0.135)	(0.0912)

Lack of tech. devices = 1 (Director)	0.784 *	0.679 ***	0.584 ***
	(0.113)	(0.102)	(0.0763)
Lack of tech. devices = 2 (Director)	0.632 ***	0.663 **	0.622 ***
	(0.106)	(0.116)	(0.0973)
Lack of tech. devices = 3 (Director)	0.477 ***	0.525 **	0.523 ***
	(0.127)	(0.142)	(0.128)
Books at home = 1 (Student)	0.913	0.118	0.885
	(0.231)	(0.110)	(0.377)
Books at home = 2 (Student)	0.932	0.140	0.777
	(0.243)	(0.131)	(0.336)
Books at home = 3 (Student)	0.888	0.114	0.741
	(0.244)	(0.107)	(0.326)
Books at home = 4 (Student)	0.864	0.139	0.807
	(0.232)	(0.130)	(0.353)
Immigrant (Student)	0.504	0.314	0.448
	(0.229)	(0.257)	(0.227)
Female (Student)	0.703	1.426	1.097
	(0.258)	(0.530)	(0.295)
Repeater (Student)	N.A.	0.346 **	0.891
		(0.165)	(0.362)
Female (Teacher)	0.961	1.073	0.965
	(0.0942)	(0.0876)	(0.0749)
Year of birth (Teacher)	1.002	1.004	1.002
	(0.00423)	(0.00375)	(0.00392)
Motivation = 1 (Teacher)	1.126	0.909	1.012
	(0.0961)	(0.0728)	(0.0791)
Motivation = 2 (Teacher)	2.248 ***	1.495 ***	1.186
	(0.315)	(0.199)	(0.148)
Motivation = 3 (Teacher)	3.044 ***	2.070 ***	1.828 **
	(0.791)	(0.459)	(0.494)
Time dedication (Teacher)	1.884 ***	0.925	1.320 **
	(0.384)	(0.194)	(0.174)
Disturbance in class = 1 (Teacher)	0.577 ***	0.836 *	0.793 **
	(0.0604)	(0.0763)	(0.0885)
Disturbance in class = 2 (Teacher)	0.514 ***	0.682 ***	0.692 ***
	(0.0592)	(0.0722)	(0.0825)
Disturbance in class = 3 (Teacher)	0.782 *	1.068	0.724 **
	(0.105)	(0.137)	(0.0999)
Class Size (Student)	1.005	0.996	0.988
	(0.0165)	(0.0160)	(0.0103)
School ownership (semi-private school)	0.827	0.894	1.122
	(0.110)	(0.123)	(0.139)
School ownership (private school)	1.824 **	1.588 *	1.070
	(0.476)	(0.428)	(0.225)
Lack of teacher training = 1 (Director)	0.835	0.853	0.756 **
	(0.123)	(0.129)	(0.102)
Lack of teacher training = 2 (Director)	0.958	0.792	0.666 **
	(0.173)	(0.146)	(0.111)
Lack of teacher training = 3 (Director)	0.740	1.047	0.392 **
	(0.307)	(0.462)	(0.177)
Lack of autonomy = 1 (Director)	0.924	1.263	1.209

	(0.143)	(0.200)	(0.176)
Lack of autonomy = 2 (Director)	0.843	1.494 **	1.596 ***
	(0.147)	(0.269)	(0.262)
Lack of autonomy = 3 (Director)	1.392	2.518 ***	1.515 *
	(0.460)	(0.857)	(0.343)
Subject (Spanish)	0.994	0.755 ***	4.109 ***
	(0.0810)	(0.0680)	(0.405)
Subject (English)	1.896 ***	0.838 *	5.680 ***
	(0.162)	(0.0768)	(0.584)
Subject (Science and Tec./Social and Civic)	N.A	0.492 ***	5.219 ***
		(0.0443)	(0.535)
Constant	0.0167	0.00157	0.00661
	(0.141)	(0.0118)	(0.0516)
Observations	5366	6785	4773
Number of schools	1105	1083	656

* Standard error in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$; ** Results are expressed in odd ratios.

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