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PISA 2022. Predictors of the mathematics achievement of Spanish students in Secondary Education

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ABSTRACT

Mathematical competence is fundamental for active, participatory and engaged participation in the 21st century, and for facing the challenges of a globalised society. This study aims to analyse the simultaneous effect of a set of predictors on the mathematical competence of Spanish students who have participated in PISA 2022. The sample consists of 28,792 Spanish students (14,465 boys, 50.24%; 14,327 girls, 49.76%), from 935 schools. Two questionnaires are used to collect data: one for students and one for school principals. A hierarchical linear model is used according to the three levels presented by the data (Level 1 = Students, Level 2 = School and Level 3 = Autonomous Community). At the first level, sex, socio-economic background, family cultural level, mathematics anxiety and self-efficacy is included; at the second level, the socio-economic background of the school; and at the third level, GDP per capita. The results show that girls experience more anxiety and less self-efficacy in mathematics than boys. The socio-economic background of the students, the cultural level of the family, mathematics anxiety and mathematics self-efficacy are significant predictors of mathematical competence. At school level, socio-economic background has an impact on achievement. These findings suggest the need to strengthen collaboration between school and family, as well as to provide specific training for teachers on how to address socio-affective feelings towards mathematics.

PISA 2022. Predictores de la competencia matemática de los estudiantes españoles de Educación Secundaria

Palabras clave:
Ansiedad ante las matemáticas
Autoeficacia
Competencia matemática
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RESUMEN

La competencia matemática es fundamental para participar de forma activa, participativa y comprometida en el siglo XXI, y afrontar los retos de la sociedad globalizada. Este estudio tiene como objetivo analizar el efecto simultáneo de un conjunto de predictores sobre la competencia matemática de los estudiantes españoles que han participado en PISA 2022. La muestra consta de 28.792 estudiantes españoles (14.465 chicos, 50.24%; 14.327 chicas, 49.76%), procedentes de 935 centros educativos. Se utilizan dos cuestionarios para recoger datos: un cuestionario para los estudiantes y un cuestionario para los directores de los centros educativos. Se utiliza un modelo lineal jerárquico según los tres niveles que presentan los datos (Nivel 1 = Alumnado, Nivel 2 = Centro y Nivel 3 = Comunidad Autónoma). En el primer nivel, se incluyen el sexo, el contexto socioeconómico, el nivel cultural de la familia, la ansiedad matemática y la autoeficacia; en el segundo nivel, el contexto socioeconómico del centro; y en el tercero, el PIB per cápita. Los resultados muestran que las chicas experimentan más ansiedad y menos autoeficacia en matemáticas que los chicos. El contexto socioeconómico del alumnado, el nivel cultural de la familia, la ansiedad ante las matemáticas y la autoeficacia en matemáticas son predictores significativos de la competencia matemática. A nivel de centro educativo, el contexto socioeconómico tiene un impacto sobre

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el rendimiento. Estos resultados sugieren la necesidad de reforzar la colaboración entre la escuela y la familia, así como proporcionar formación específica al profesorado sobre cómo abordar el sentimiento socioafectivo hacia las Matemáticas.

Introduction

Mathematical competence, the primary focus of the 2022 Programme for International Student Assessment (PISA), is defined by the Organisation for Economic Cooperation and Development (OECD) as students' ability to reason mathematically and solve problems in various contexts (OECD, 2023a). In this sense, the acquisition of mathematical competence has become increasingly relevant due to factors such as the digitalisation of many aspects of life and the globalised economy. These developments require citizens with a high level of mathematical literacy to participate in a reflective and committed way in the 21st century (OECD, 2023a).

Previous studies have highlighted several factors influencing mathematical competence: gender, student's socio-economic context, family cultural capital, mathematics anxiety, mathematics self-efficacy, school socio-economic context, and differences among autonomous communities.

Regarding gender, Baye and Monseur (2016) found differences in mathematics performance favouring boys, which they attributed to the sociocultural and economic context of schools (Cascella et al., 2022). Molina-Muñoz et al. (2023) identified variables affecting mathematics performance in Spain using data from PISA 2018, finding that gender is a significant predictor of performance. This aligns with other international research findings from PISA 2015 (Zhu et al., 2018). Other factors underlying gender differences in mathematics performance include mathematics anxiety, which is higher in females than in males (Justicia-Galiano et al., 2023; Van Mier et al., 2019), and self-efficacy, which is lower in females than in males (Ayuso et al., 2021; Reilly et al., 2019).

Coleman et al. (1966) found that students' socio-economic context, the second factor, significantly impacts academic performance. Lee et al. (2019) analysed the consistency of context effects across PISA editions from 2003 to 2012. Their results demonstrate a significant correlation between students' socio-economic status and mathematics performance over the years, aligning with other international research findings (Rozgonjuk et al., 2023; Xie & Ma, 2019). These studies suggest that students from higher-income families score higher in mathematics performance than those from lower-income families (Jeffries et al., 2020; Wang et al., 2023). Consequently, students from disadvantaged backgrounds face greater challenges in transferring their mathematical knowledge to mathematical literacy compared to their more advantaged peers (Kang & Cogan, 2022).

The third factor, family cultural capital, has been found to impact mathematics performance (Long & Pang, 2016; Qiu & Leung, 2022; Rindermann & Ceci, 2018). The highest educational qualification achieved by each parent serves as a significant predictor of performance (Lee & Borgonovi, 2022), influencing students' orientation towards mathematics-related careers (Codiroli, 2019).

The fourth factor, mathematics anxiety, is defined as a feeling of tension, apprehension, or fear that interferes with mathematics performance (Ashcraft, 2002). Various studies (Barroso et al., 2021; Luttenberger et al., 2018; Passolunghi et al., 2020; Van der Beek et al., 2017) have found a negative association between anxiety and mathematics performance, with higher anxiety levels correlating with poorer results. Chan and Liem (2023) employed a multilevel model that revealed a negative correlation between mathematics anxiety levels and performance. Analysing data from 4,978 American students participating in PISA 2012, Wang (2023) demonstrated the negative impact of anxiety on motivation to learn mathematical concepts. Similarly, Xiao and Sun (2021) found that American students in PISA 2012 with low mathematics anxiety and high motivation scored higher than those with higher anxiety levels. Schmitz et al. (2019) identified mathematics anxiety as a significant predictor with a negative impact on performance in a sample of 189 secondary school students in the Netherlands, corroborating the findings of Novak and Tassell (2017). Demedts et al. (2022) analysed the relationship between mathematics anxiety and performance among 181 secondary school students from Flanders (Belgium). Their results indicate that students exhibit a stable anxiety trait when facing high-difficulty tasks, compared to temporary anxiety for easier tasks. This indicates that anxiety affects students with lower mathematical competence more severely than those with higher competence (Weissgerber et al., 2022).

The fifth factor, self-efficacy in mathematics, refers to students' beliefs about their abilities to perform mathematical tasks successfully at their academic level (Schunk, 1991). Lee and Stankov (2018) analysed the influence of self-efficacy on mathematics performance among 485,490 students from 64 countries participating in PISA 2012. Their results show that self-efficacy is a significant predictor of performance, with a one-unit increase in self-efficacy associated with a 0.25 standard deviation increase in performance. Similarly, Gabriel et al. (2018) found that self-efficacy had the greatest impact on performance in a sample of 14,481 Australian students in the same PISA edition. This aligns with Gjicali and Lipnevich's (2021) study, which indicated that American students' belief in their abilities significantly impacted their mathematical competence in PISA 2012. These findings are consistent with other research (Borgonovi & Pokropek, 2019; Keller et al., 2022) showing that students with high self-efficacy tend to be oriented towards STEM (Science, Technology, Engineering, and Mathematics) fields. Rodríguez et al. (2020) revealed the impact of self-efficacy on the mathematical competence of Spanish students participating in PISA 2018. Schöber et al. (2018) found that the effect of self-efficacy on performance is mediated by students' motivation towards mathematics, influencing their knowledge of the subject and its application in problem-solving (Pennington et al, 2021).

Regarding the socio-economic context of schools, Murphy (2019) identified it as a predictor of mathematical competence, explaining performance differences based on the socio-economic context of students attending the school (Boda et al., 2022; Ker, 2016). Liu et al. (2015) analysed the effect of schools' socio-economic context on performance in 28 OECD countries participating in PISA 2003. Their results show that students attending schools in advantaged contexts outperform those in disadvantaged environments, attributing this to a more favourable school climate in the former.

Concerning performance differences among autonomous communities in Spain, the resources allocated to education by each autonomous community do not, by themselves, fully explain the regional variations in performance (López et al., 2016).

The present study

The literature review highlights further research on the influence of the aforementioned factors on mathematical competence. This study addresses a knowledge gap in the field by utilising robust national-level samples from the PISA study and employing a three-level hierarchical model (students, schools, and autonomous communities) in Spain. It incorporates the influence and effect size of the two psychological variables that have the greatest impact on mathematical competence: anxiety and self-efficacy. This research provides valuable insights for policymakers, identifying student and school variables that can be targeted to improve mathematical competence through educational policy. Additionally, it offers teachers guidance on didactic actions that can help reduce anxiety and reinforce self-efficacy in mathematics.

The general objective of this research is to examine the simultaneous effect of a series of predictors on the mathematical competence of Spanish students participating in PISA 2022, across the three levels of aggregation present in the data. First, the study determines the influence of student-level variables on mathematical competence, including gender, student's socio-economic context, family cultural capital, mathematics anxiety, and mathematics self-efficacy. Second, it analyses the influence of school-level and regional-level factors on performance, specifically the socio-economic context of the school and the gross domestic product (GDP) of the autonomous communities. Based on these objectives, the following hypotheses are proposed: Hypothesis 1 = Student gender is a significant predictor of mathematics performance; Hypothesis 2 = Students' socio-economic context significantly predicts their mathematics performance; Hypothesis 3 = Family cultural capital is a significant predictor of students' mathematics performance; Hypothesis 4 = Mathematics anxiety has a significant effect on mathematics performance; Hypothesis 5 = Mathematics self-efficacy has a significant effect on mathematics performance; Hypothesis 6: The socio-economic context of the school is a significant predictor of students' mathematics performance; and, Hypothesis 7: The GDP per capita of autonomous communities explains the differences in mathematics performance between regions.

Method

This study employs a non-experimental, *ex post facto* research design. In this approach, there is no direct manipulation of the independent variables, nor is it possible to assign participants randomly to experimental groups, as the phenomena under investigation have already occurred (Kerlinger & Lee, 2002).

Participants

The eighth edition of PISA, conducted in 2022, involved 30,800 Spanish students aged 15-16 years (15,561 boys, 50.52%; 15,239 girls, 49.48%) from 966 educational centres across 17 autonomous communities and two autonomous cities (Ceuta and Melilla). Most of these students were in the 4th year of Compulsory Secondary Education (*Educación Secundaria Obligatoria* - ESO) (Ministry of Education, Vocational Training & Sports, 2023). The final sample for this study comprises 28,792 Spanish students (14,465 boys, 50.24%; 14,327 girls, 49.76%) from 935 schools. In configuring the final sample, 2,008 students were excluded due to incomplete information across all variables. The treatment of missing values is as follows: (1) Little's (1988) test was performed to determine if the pattern of missing data was characterised by total randomness and absence of bias (Missing Completely At Random [MCAR]); (2) Using SPSS 29, Little's MCAR test yielded a chi-square statistic of 374.51 and p = .592; (3). As p is greater than .05, it is confirmed that the pattern of the missing values does not depend on the values of the data (IBM, 2024), indicating that they are MCAR.

Table 1
Data from the PISA 2022 sample in Spain

Autonomous community/city	*N*	Schools	Median	Standard deviation
Andalucía	1.610	51	457	80.94
Aragón	1.359	44	487	79.29
Asturias	1.561	49	495	80.03
Cantabria	1.648	52	495	77.24
Castilla-La Mancha	1.453	51	464	74.65
Castilla y León	1.687	54	499	77.76
Cataluña	1.503	50	469	83.35
Extremadura	1.655	54	469	77.65
Galicia	1.715	57	486	75.16
Islas Baleares	1.492	51	471	77.40
Islas Canarias	1.420	52	447	75.92
La Rioja	1.361	47	493	82.04
Madrid	1.726	52	494	79.67
Murcia	1.605	52	463	78.53
Navarra	1.741	52	492	78.64
País Vasco	3.118	94	482	77.31
Valencia	1.534	51	473	78.65
Ceuta	345	12	395	77.55
Melilla	259	10	404	81.19
Spain	28.792	935	473	78.57

Source: Own elaboration.

As the missing data pattern is MCAR, the listwise deletion method was used. This method involves eliminating cases with one or more missing values. This approach is appropriate for the following reasons. First, the proportion of lost data is smaller than that of the total sample (only 6% in this case). Second, it preserves the integrity of the socio-economic index variable, which is created from the average of three variables (highest educational level of parents, higher professional status of parents, and household resources). Third, it provides a complete set of cases with accurate data (Enders, 2010).

The choice of listwise deletion is further supported by considerations regarding the socio-economic index variable (Murillo, Martínez-Garrido, & Graña, 2023), as substituting a lost value with an estimate could affect the exact value of this composite index. Table 1 presents the measures of central tendency and dispersion of mathematical competence for each autonomous community and city in Spain.

Instruments

This study analyses variables included in the following instruments of the PISA 2022 Study (Ministry of Education, Vocational Training & Sports, 2023):

The student questionnaire. It collects information on the family, school, and academic environment, with specific focus on mathematics anxiety and self-efficacy. The questionnaire demonstrates good internal consistency, with a Cronbach's alpha coefficient of 0.81 (Hernández-Sampieri & Mendoza, 2018). Item formulation adheres to criteria that ensure response reliability and construct validity for anxiety and self-efficacy measures (Arias et al., 2020; Niessen et al., 2016; OECD, 2023a). These criteria include a balance between positively and negatively worded items and the use of a four-point Likert scale (1 = Strongly disagree, 2 = Disagree, 3 = Agree, 4 = Strongly agree). The reliability and validity of the anxiety (Cronbach's alpha = .83) and self-efficacy (Cronbach's alpha = .80) constructs, demonstrating good internal consistency, were established through a rigorous three-stage process. Initially, mathematics experts in each participating country administered the questionnaire to a sample of 100 students in a small-scale validation test, identifying items that scored negatively or failed to measure their intended aspects. Subsequently, the items were modified and linguistically revised to ensure appropriate translation for each country. Finally, a field study was conducted to validate the constructs and measurements prior to the main test, allowing for the identification and rectification of items with insufficient scoring validity and reliability before large-scale implementation (OECD, 2023a).

The school questionnaire. It is directed at principals and collects data on the administrative and didactic organisation of educational centres and learning environments. This questionnaire's Cronbach's alpha coefficient is .90, indicating excellent internal consistency (Hernández-Sampieri & Mendoza, 2018).

Procedure

The data collection procedure, endorsed by the OECD scientific committee and comprising international experts in mathematical competence, was conducted in April 2022 across 81 participating countries. The results were published in December 2023 (OECD, 2024). The process adheres to a rigorous quality control protocol divided into three stages. In the first stage, school directors receive manuals detailing questionnaire administration procedures. In the second, test administrators are selected based on two validity-ensuring criteria: they must not teach the group being tested nor belong to any school in the sample. In the third stage, a member of the scientific team provides training to the test administrators at each centre (OECD, 2024).

The assessments are administered digitally on laptops provided by the National Institute for Educational Evaluation (*Instituto Nacional de Evaluación Educativa* - INEE), the unit within the Ministry of Education and Vocational Training responsible for the PISA study in Spain. Students are allotted two hours for the mathematical competence test and one hour to complete a questionnaire about their family, school, and academic context.

Student performance in mathematical competence (the dependent variable) is calculated using the Rasch model and reported on scales with a mean score of 500 points and a standard deviation of 100 (OECD, 2023a).

The PISA 2022 database provides ten plausible values for each student's mathematics test performance (480.91, 482.17, 481.83, 482.47, 482.13, 480.83, 482.76, 482.15, 481.35, and 481.99) (OECD, 2023b). To determine mathematical competence, independent estimates are made for each of these ten plausible values, and the average score is calculated (Wu & Adams, 2002).

PISA establishes six levels of mathematical competence: Level 1 (0–419 points), Level 2 (420–481), Level 3 (482–544), Level 4 (545–606), Level 5 (607–668), and Level 6 (669 and above). Spanish students achieved an average score of 473 points, aligning with the OECD average (472 points) and the European Union (EU) countries' average (474 points). Notably, boys outperformed girls in mathematical competence in Spain (boys = 478 points; Girls = 468 points), with a 10-point difference. This gender gap is comparable to the OECD average (boys = 477 points; girls = 468 points; a 9-point difference) and the EU countries' average (boys = 479 points; girls = 469 points; a 10-point difference) (Ministry of Education, Vocational Training & Sports, 2023).

Data analysis

Linear hierarchical model

The procedure that confirms the assumptions of the linear hierarchical model is divided into four stages. In the first stage, normal distribution is assessed using the Kolmogorov-Smirnov Z test, with values greater than 0.05 confirming normal distribution. As part of the second stage, extreme values or outliers are detected and discarded to prevent distortion in data interpretation. In the third stage, the assumption of homoscedasticity is verified by means of the Levene test ($p > .05$). In the fourth stage, the scatter plot of the resources shows a random, unbiased pattern, confirmed by a standardised residual value of 2,076. This study uses a linear hierarchical model to analyse the effect of a set of predictors on the dependent variable, respecting the nested structure of the data: students, schools, and autonomous communities (Tourón et al., 2023).

At the first level (students), the following variables of the student questionnaire are considered:

- Gender. Dummy variable (0 = boy, 1 = girl).
- Socio-economic context of the students (ISEC). An index calculated from the average of the following three variables.
  1 Parents' highest educational level: The average of the students' responses to four items (two items each for the father and mother), extracted from the student questionnaire (Student Questionnaire, 2024):
    - Item 1. What is the highest level of education your mother completed? (0 = Did not finish primary education, 1 = Primary education, 2 = Secondary education, 3 = Intermediate level training cycles, 4 = A-Levels).
    - Item 2. Does your mother have any of the following degrees? (0 = Yes/1 = No).
      2.1 Higher level training cycles
      2.2 Degree or diplomacy
      2.3 Master's or bachelor's degree
      2.4 Doctorate
    - Item 3. What is the highest level of education your father completed?
    - Item 4. Does your father have any of these degrees?
  2 Parents' Highest Professional Status: Based on the average of the students' responses to two open-ended questions for each parent (Student Questionnaire, 2024): What is your mother's main job? What does your mother do in her main job? What is your father's main job? What does your father do in his main job? Responses are coded as follows: 0 = Employed, 1 = Doing housework/raising children, 2 = Studying, 3 = Retired, pensioner, or receiving unemployment benefit
  3 Household resources: Constructed from the average of students' responses to six items:
    3.1 Are the following items present in your house? (0 = Yes/1 = No), including a room of your own, a laptop, educational applications, or computer programs, among others (Student questionnaire, 2024).
    3.2 How many of the following things are present in your house? (0 = None, 1 = One, 2 = Two, 3 = Three or more), including cars, mopeds, and toilets, among others (Student questionnaire, 2024).
    3.3 How many digital devices with a screen are there in your house? (0 = None, 1 = One, 2 = Two, 3 = Three, 4 = Four, 5 = Five, 6 = 6 to 10, 7 = More than 10) (Student questionnaire, 2024).
    3.4 How many digital devices are there in your house? (0 = None, 1 = 1 or 2, 2 = 3-5, 3 = More than 5, 4 = I do not know), including televisions, desktop computers, laptops or notebooks, among others (Student questionnaire, 2024).
    3.5 How many books are there in your house? (0 = 0-10 books, 1 = 11-25 books, 2 = 26-100 books, 3 = 101-200 books, 4 = 201-500 books, 5 = More than 500 books) (Student questionnaire, 2024).
    3.6 How many of the following types of books are there in your house? (0 = None, 1 = 1-5, 2 = 6-10, 3 = More than 10, 4 = I do not know), including religious books, classic lit-

erature, contemporary literature, among others (Student questionnaire, 2024).

- *Cultural capital of the family*. An index derived from the average of the highest educational level achieved by each parent (0 = Pre-school education; 1 = Primary education; 2 = Lower secondary education; 3 = Secondary education without access to higher education; 4 = Secondary education with direct access to higher education; 5 = Higher education for professional practice; 6 = Short-cycle higher education, at least two years; 7 = Diploma or Degree, three to four years; 8 = Bachelor's or Master's degree, at least five years; 9 = Doctorate). This is a standardised variable.
- *Mathematics anxiety*. The index is derived from the average of the students' responses to six items (Student Questionnaire, 2024). Responses are recoded for clarity: (0 = Strongly Disagree, 1 = Disagree, 2 = Agree, 3 = Strongly Agree) (Ministry of Education, Vocational Training & Sports, 2023). The items are as follows: (1) I often worry about having difficulties in mathematics classes, (2) I get very stressed when I have to do mathematics homework; (3) I get very nervous when I work on mathematics problems; (4) I feel unable to solve a mathematics problem; (5) I am worried about getting bad grades in mathematics and, (6) I am afraid of failing mathematics. The average of these items constitutes the mathematics anxiety index.
- *Self-efficacy in mathematics*. This is another index created by PISA 2022, based on students' confidence in ten statements. Responses were recoded as follows: (0 = Very unsafe, 1 = Unsafe, 2 = Safe, 3 = Very safe) (Ministry of Education, Vocational Training & Sports, 2023). The statements are as follows: (1) Extract mathematical information from diagrams, graphs, or simulations; (2) Interpret mathematical solutions to real-life problems; (3) Use the concept of statistical variation to make a decision; (4) Identify the mathematical aspects of a real problem; (5) Identify the limitations and assumptions on which mathematical models are based; (6) Represent a situation mathematically using variables, symbols, or diagrams, (7) Evaluate the importance of the patterns observed in the data, (8) Code or program computers; (9) Work with mathematical computer systems (e.g., spreadsheets, programming software, graphing calculators), and, (10) Calculate the properties of an irregularly shaped object. The average of these items constitutes the self-efficacy in mathematics index.
- At the second level (school), the socio-economic context of the school is considered based on the average ISEC of the students attending the school. This is a standardised variable.
- At the third level (autonomous community), GDP per capita is included based on the information collected in the school questionnaire.

The analyses are performed using the MLwiN 2.36 program (Charlton et al., 2024; Rasbash et al., 2016), which allows for the calculation of estimates using the *Iterative Generalised Least Squares (IGLS)* procedure (Goldstein, 2003), SPSS 29, and R 4.4 (Huang, 2022). This approach is the most suitable when the diagnosis of the residuals is non-zero and reduces the risk of erroneous inferences.

Results

Anxiety

The results of the Student's *t*-test reveal that Spanish boys scored 0.11 points on the *anxiety* index, while Spanish girls scored 0.61 points. The level of significance (p = .00) indicates that the observed differences between the groups are highly reliable and likely represent genuine differences in the underlying population. The student *anxiety* index in Spain (0.37 points) is above the average for OECD and EU countries, both of which are 0.17 points. The gender difference in Spain is 0.50 points, which slightly exceeds the difference in the total of EU (0.49 points) and OECD countries (0.46 points) (Ministry of Education, Vocational Training & Sports, 2023). The eta-squared coefficient (η^2 = 0.063) is calculated to measure the effect size, indicating a medium effect of anxiety on mathematics performance (Tourón et al., 2023).

Table 2
Null model estimation

Fixed component	
Parameter	Estimation (Standard Error)
Constant	479.98 (5.19)
Random component (Variance in Mathematical Competence)	
Level 1. Students	6160.93 (49.66)
Level 2. Schools	1178.77 (63.16)
Level 3. Autonomous Community	610.37 (202.48)
−2 Restricted Log Likelihood	353699.55
Akaike Information Criterion (AIC)	353715.55
Number of Parameters	4

Source: Own elaboration.

Self-efficacy

The results of the Student's *t*-test reveal a significant difference in mathematics *self-efficacy* between Spanish boys and girls. Spanish boys scored 0.164 points on the self-efficacy scale, while Spanish girls scored −0.136. The high level of statistical significance (p = 0.00) indicates that these observed differences between the groups are highly reliable and likely represent genuine disparities in the underlying population. The average mathematics *self-efficacy* index for Spanish students (0.03) slightly exceeds that of both OECD and EU countries, which both stand at 0.01. Gender differences in mathematics self-efficacy in Spain (−0.30) are comparable to the average differences observed in OECD (−0.33) and EU countries (−0.31) (Ministry of Education, Vocational Training & Sports, 2023). The eta-squared coefficient (η^2 = 0.012) implies a small effect size for the impact of self-efficacy on mathematics performance (Tourón et al., 2023). For the hierarchical linear model, the null model is first estimated, in which four parameters are calculated: the intercept and variances of the residuals at the three levels of aggregation (Acevedo, 2008; Ruiz de Miguel & Castro, 2006):

$$y_{ijk} = \beta_{ojk} + e_{ijk}$$

$$\beta_{0jk} = \beta_{0k} + u_{ojk}$$

$$\beta_{ok} = \beta_{00} + v_{ok}$$

Here, i = first-level units, students j = second-level units, the schools k = third-level units, the autonomous communitiesY_{ijk} represents the average performance in mathematical competence of student i of school j in autonomous community k. β_{0jk} represents the general average performance of student i of school j in the autonomous community k. It indicates the average performance of the students at a given school in an autonomous community. β_{0k} includes the average performance of school j in autonomous community k. β_{00} is the general average yield between the autonomous communities. e_{ijk} is the residual of the first level, the students. u_{ojk} is the random effect of the second level, the schools. v_{ok} is the residue or variance between the estimated value for the autonomous community and its real value.

The criterion for determining parameter significance is based on a significance level of α = .05. A parameter is considered significant if the ratio of its estimate to its standard error exceeds 1.96 (Gaviria & Castro, 2004). Table 2 reveals that the average performance in mathematical competence across all students is 479.98

Table 3
Model with explanatory variables at level 1

Fixed Component	
Constant	468.59 (4.76)
Gender	−7.45 (0.61)
Student socio-economic context	13.52 (0.49)
Family cultural capital	6.28 (0.47)
Math anxiety	−9.26 (0.56)
Self-efficacy in mathematics	7.64 (0.33)
Random Component	
Between students	5649.36 (54.17)
Between schools	918.84 (52.15)
Between autonomous communities	476.23 (229.06)
Reason for plausibility	326120.85
Akaike information criterion (AIC)	326137.85

Source: Own elaboration.

Table 4
Model with explanatory variables at level 2

Fixed component	
Intercept	477.16 (4.32)
Gender	−6.07 (0.76)
Student socio-economic context	11.24 (0.58)
Family cultural capital	5.63 (0.56)
Mathematics anxiety	−8.27 (0.59)
Mathematics self-efficacy	6.21 (0.32)
School socio-economic status	10.17 (0.89)
Random Component	
Between students	5281.26 (42.17)
Between schools	645.27 (33.15)
Between autonomous communities	427.84 (139.04)
Likelihood Ratio	314057.61
Akaike information criterion (AIC)	314073.61

Source: Own elaboration.

points. This performance varies significantly at three levels: (1) Student level (Level 1): 6160.93 / 49.66 = 124.06; School level (Level 2): 1178.77 / 63.16 = 18.66; and, (3) Autonomous community level (Level 3): 610.37 / 202.48 = 3.01. The significance of these parameters indicates the existence of unexplained variance in performance at all three levels: among students, between schools, and across autonomous communities. This justifies the development of a more comprehensive model to explain the maximum possible amount of variance at each level. The likelihood ratio for this null model is 353,699.55, which includes the four parameters. This value will serve as a baseline for comparison with the final, more complex model.

Intraclass correlation coefficient

The intraclass correlation coefficient (ICC) is a measure of internal group homogeneity, individual-level unit similarity, and macro-level unit differences (Barcikowski, 1981; Ruiz de Miguel & Castro, 2006). Using the data from Table 2, we can calculate the ICC between levels: First, the autocorrelation of students within educational centres is as follows: p = 1178.77/(6160.93 + 1178.77 + 610.37) = .1482. This value indicates that 14.82% of the total variance is variance between centres. Second, the autocorrelation of students within autonomous communities is as follows: p = 610.37/(6160.93 + 1178.77 + 610.37) = .0767. Thus, 7.67% of the total variance is between autonomous communities. Third, the autocorrelation of schools within autonomous communities is as follows: p = 610.37/(1178.77 + 610.37) = .3411. This reveals that 34.11% of the total variance is between schools within autonomous communities. These values demonstrate the homogeneity of units within each level, justifying the use of multilevel models to explain variance across the three levels using information from the independent variables. The multilevel model can be expressed as follows:

$$Y_{ijk} = \beta_{0jk} + \beta_{1jk}\text{Gender}_{ijk} + \beta_{2jk}\text{ISEC}_{ijk} + \beta_{3jk}\text{Anxiety}_{ijk} + \beta_{4jk}\text{Self-efficacy}_{ijk} + \beta_{5k}\text{ISECEN}_{jk} + \varepsilon_{ijk}$$

Here, Y_{ijk} is the average mathematical competence performance of student i of school j in autonomous community k. $Gender_{ijk}$ is 1 if the student is a female and 0 if they are male. $ISEC_{ijk}$ is the student's socio-economic context. $Anxiety_{ijk}$ is the student's mathematics anxiety index. $Self\text{-}efficacy_{ijk}$ is the student's mathematics self-efficacy index. $ISECEN_{jk}$ is the average socio-economic context of the school.

Table 3 presents the results of the model estimation with first-level explanatory variables, prior to allowing coefficients to vary at level 2.

Based on the data presented in Table 3, the intercept value is 468.59 points, which is slightly lower than the value in the null model. This discrepancy arises because the reference group for this intercept differs from that of the null model; specifically, it represents the expected performance of female students with a socio-economic context at the sample mean. The explanatory variables incorporated into the random component demonstrate significant effects on mathematical competence. Female students tend to perform lower than their male counterparts in mathematical competence, with an estimated average decrease of −7.45 points. Performance improves by 13.52 points for each unit increase in *socio-economic context*, while a one-point rise in the *cultural capital of families* corresponds to an increase of 6.28 points in performance. Mathematics *anxiety* has been found to be a significant predictor with a negative effect on performance, resulting in a 9.26-point decrease for each unit increase in anxiety. Conversely, *self-efficacy* in mathematics exhibits a positive effect on performance, with each unit increase in self-efficacy associated with an increase of 7.64 points in performance. Table 4 presents the results of the model estimation with the explanatory variables of the second level.

Table 4 shows that the intercept value increases to 477.16 points, with minor changes in the covariances. Female students perform lower than boys in mathematical competence, with the estimated average decreasing by 6.07 points for girls. For each point increase in the *socio-economic context*, performance increases by 11.24 points. Similarly, for each point increase in the family's cultural capital, performance increases by 5.63 points. The average *socio-economic context of students* attending an educational centre is also included, showing a positive effect on mathematical competence. As the average *socio-economic context of the school* increases by one point, the average performance of the student body increases by 10.17 points. Regarding mathematics *anxiety*, for every point increase, performance decreases by 8.27 points. In terms of *self-efficacy* in mathematics, for every point increase in self-efficacy, performance increases by 6.21 points. Table 5 presents the results of the fixed and random components of the final model.

Table 5 shows that the intercept value is 485.89 points. Female students perform lower than male students in mathematical competence, with the estimated average decreasing by 4.29 points for girls, which explains the gender gap among Spanish students. The *socio-economic context of the students* is a significant predictor with a positive effect on mathematical competence. For each point

Table 5
Ultimate model

Fixed Component	
Intercept	485.89 (3.71)
Gender	−4.29 (0.84)
Student socio-economic context	10.31 (0.65)
Family cultural capital	4.04 (0.64)
Mathematics anxiety	−7.93 (0.45)
Mathematics self-efficacy	5.19 (0.42)
School socio-economic status	8.72 (0.91)
Random Component	
Between students	4913.12 (38.09)
Between schools	532.16 (19.42)
Between autonomous communities	369.18 (83.43)
Likelihood Ratio	303336.97
Akaike information criterion (AIC)	303352.97
Number of Parameters	10

Source: Own elaboration.

increase in the socio-economic context, performance increases by 10.31 points. Similarly, for each point increase in the family's cultural capital, performance rises by 4.04 points. Furthermore, the *socio-economic context of the school* has a positive effect on mathematical competence. As the average socio-economic context of the school increases by one point, the average performance of students increases by 8.72 points. Mathematics *anxiety* is a significant predictor with a negative effect on performance. For every point increase in anxiety, performance decreases by −7.93 points. Conversely, *self-efficacy* in mathematics is a significant predictor with a positive effect on performance—for each point increase in self-efficacy, performance increases by 5.19 points. The GDP per capita of the autonomous communities is not a significant predictor of mathematical competence.

Regarding the random component of the model, the calculated variances are also significant. To evaluate the model fit, the likelihood ratio of the definitive model is compared with that of the null model. The difference in their respective deviations is 50362.58 with six degrees of freedom, which is significant at the 0.01 level. This confirms the superior fit of the definitive model compared to the null model in explaining students' mathematical competence.

Furthermore, the results show that the log-likelihood and the Akaike information criterion progressively decrease in the intermediate models, indicating improved goodness of fit in the definitive model. To determine the proportion of variance in the dependent variable explained by the set of predictors included in the model, the random parameters of the definitive model are compared with those of the null model using the R^2 coefficient (Snijders & Bosker, 2012; Student Questionnaire, 2024). The predictor variables included in the model explain 20% of the differences between students ($R^2 = 0.2025$), 55% of the differences between schools ($R^2 = 0.5485$), and 39% of the differences between the autonomous communities ($R^2 = 0.3951$).

Discussion

This research examines the simultaneous effect of multiple predictors on the mathematical competence of Spanish students participating in PISA 2022. To this end, a multilevel regression model is employed, respecting the three levels of aggregation in the data: students, schools, and autonomous communities. The final model explains 20% of the differences between students, 55% between schools, and 39% between autonomous communities.

First, the study determines the influence of student-associated variables on mathematical competence (gender, socio-economic context, family cultural capital, anxiety, and self-efficacy) by testing seven hypotheses. The results support the first hypothesis that gender is a significant predictor of mathematical competence, with girls performing lower, corroborating previous findings (Baye & Monseur, 2016; Zhu et al., 2018). This difference is attributed to girls experiencing more mathematics anxiety than boys, consistent with other studies (Justicia-Galiano et al., 2023; Van Mier et al., 2019), and demonstrating lower self-efficacy than boys (Ayuso et al., 2021; Reilly et al., 2019).

The second hypothesis, positing that students' socio-economic context predicts mathematical competence, is also supported. This aligns with previous research findings (Coleman et al., 1966; Rozgonjuk et al., 2023; Xie & Ma, 2019) and the 2003, 2006, 2009, and 2012 editions of PISA (Lee et al., 2019). The third hypothesis, stating that family cultural capital significantly predicts mathematical competence, is supported. Higher parental education levels correlate with higher student performance, confirming results from other studies (Lee & Borgonovi, 2022; Long & Pang, 2016; Qiu & Leung, 2022; Rindermann & Ceci, 2018). This factor also influences students' orientation towards mathematics-related degrees (Codiroli, 2019).

The fourth hypothesis, proposing that mathematics anxiety negatively affects mathematical competence, is confirmed. This aligns with previous research (Luttenberger et al., 2018; Schmitz et al., 2019; Van der Beek et al., 2017) and PISA 2012 results from the United States (Wang, 2023; Xiao & Sun, 2021), which found a negative association between anxiety index and mathematics performance (Ministry of Education, Vocational Training & Sports, 2023). The literature suggests that girls experience more mathematics anxiety than boys (Justicia-Galiano et al., 2023; Van Mier et al., 2019), while fathers tend to hold higher expectations for their sons than for their daughters in STEM fields.

The results support the fifth hypothesis, which posits that self-efficacy in mathematics is a significant predictor of mathematical competence. This is in alignment with previous studies on the PISA 2012 edition (Gabriel et al., 2018; Gjicali & Lipnevich, 2021; Lee & Stankov, 2018), the 2018 edition of PISA (Rodríguez et al., 2020), and other research (Borgonovi & Pokropek, 2019; Keller et al., 2022), all of which indicate a positive correlation between students' self-efficacy index and their level of mathematical competence. However, there is a discrepancy between these results and the findings of the PISA 2022 Report: "[I]n Spain as a whole, situations similar to those observed in the international context can be seen. The autonomous communities are distributed proportionally between the four quadrants determined by the averages in the [mathematics self-efficacy] index and performance for the OECD" (Ministry of Education, Vocational Training & Sports, 2023, p. 164).

Second, this study analysed the influence of the socio-economic context of the school and the GDP of the autonomous communities on student performance. The results support the sixth hypothesis, which states that the school's socio-economic context is a significant predictor of performance. This finding is consistent with other research (Boda et al., 2022; Ker, 2016; Murphy, 2019), which has identified performance differences based on the socio-economic context of the students attending the school. It also aligns with the results of the PISA 2003 report (Liu et al., 2015), which emphasises that students attending schools in advantaged environments perform better than those in disadvantaged ones.

The results lead to the rejection of the seventh hypothesis, which proposed that GDP per capita explains the differences in performance between the autonomous communities. This outcome is in agreement with López et al. (2016), who argue that GDP does not solely account for regional differences, suggesting that the sociocultural characteristics of each autonomous community must be considered. The findings of this study have several important implications for the didactics of mathematics. First, the significant impact of family cultural capital on students' mathematical competence suggests the need to strengthen collaboration between schools and families. This collaboration should involve diverse work strategies tailored to parents' educational levels.

Second, the observed negative effect of mathematics anxiety on performance necessitates specific training for teachers (seminars, conferences and workshops) focused on addressing the socio-affective aspects of mathematics education within the school setting. Importantly, this training must be contextualised, considering the unique characteristics of each school's environment, grade level, and student population. Third, although the effect of self-efficacy in mathematics on performance is modest, it remains significant. This finding suggests the value of designing, implementing, and evaluating programmes to foster curiosity towards mathematics among school students. One potential approach is the creation of collaborative teaching groups involving secondary schools and universities, which can help bridge the gap between these educational levels. This synergy could facilitate the design of activities based on competencies and real-world learning situations.

Fourth, the impact of a school's socio-economic context on students' mathematical competence highlights the need for more equitable resource allocation. Schools in disadvantaged areas should receive additional resources to develop students' mathematical competence on par with schools in more advantaged environments.

A limitation of this study is the loss of information due to missing values. However, the Little test (1998) confirmed that the pattern of missing data is MCAR, characterised by total randomness and absence of bias. Given this MCAR scenario, the list deletion imputation method was employed, analysing only complete cases. As the proportion of deleted data (6%) represents a small percentage of the total sample, it is unlikely to affect the study's conclusions significantly.

This work opens up new avenues for investigating mathematics performance. Future studies could delve deeper into the gender gap in mathematics, exploring factors within the family context, such as parental academic expectations for STEM-related professions and parental involvement in mathematical activities. These factors may influence self-efficacy and anxiety levels in students.

In conclusion, this study analyses the influence of various predictors on the mathematical competence of Spanish students participating in PISA 2022. It highlights the influence and effect size of self-efficacy and anxiety on mathematical performance.

CRediT authorship contribution statement

Pablo Javier Ortega-Rodríguez: conceptualization, data curation, formal analysis, investigation, methodology, project administration, resources, software, supervision, validation, visualization, writing - original draft, writing - review & editing.

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