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GENDER GAPS IN UNDERGRADUATE MATHEMATICS PERFORMANCE IN ROMANIA: AN ANALYSIS USING GENERAL LINEAR MODELS *

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Abstract

This paper investigates gender gaps in mathematics performance among Romanian Baccalaureate students across four educational profiles: Mathematics-Informatics, Natural Sciences, Technological, and Pedagogical, between 2017 and 2023. Using descriptive statistics, and statistical analyses such as t-tests and General Linear Models, the study reveals consistent gender disparities in mathematics performance, with female students generally outperforming male students. The results highlight significant variations in performance across the different educational profiles, pointing to a need for profile-specific educational interventions. The spatial analysis underscores the need for targeted strategies that address not only gender gaps, but also regional inequalities. The findings suggest that Romania's policy of equal access to education may not fully address the differences in educational outcomes, thereby calling for tailored interventions to bridge the performance gaps across gender, profile, and region.

Keywords: Baccalaureate performance, Romanian education, Descriptive analysis, Educational profiles, Mathematics achievement, General Linear Models

JEL Classification: I21, C12, I24

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1. Introduction

STEM (Science, Technology, Engineering, and Mathematics) education is highly important and plays a critical role in preparing individuals and societies for the challenges and opportunities of the modern world. Fur undergraduate students, Mathematics is a relevant part of their education related to enhancing their skills. A large percentage of future jobs will require STEM-related skills, such as data analysis, programming, robotics, biotechnology and engineering design. These skills are essential in industries like information technology, healthcare, renewable energy, advanced manufacturing and aerospace. For example, programming and robotics play a critical role in automating manufacturing processes, while biotechnology advancements are driving innovation in medical research and pharmaceuticals. Also, data analysis and engineering design are pivotal in developing sustainable energy solutions and infrastructure projects (U.S. Bureau of Labor Statistics, 2024)..

This paper addresses the gender gaps in Mathematics performance at the undergraduate level in Romania, a country that expresses striking differences in the field. On one hand, a number of talents gain remarkable recognition in mathematics national and international contests; on the other hand, according to the most recent results from PISA evaluations, Romanian students performed below the OECD average in mathematics on the 2022 PISA assessment, scoring 428 points compared to the OECD average of 472 points. Only 51% of Romanian students achieved basic proficiency (Level 2 or above), significantly lower than the OECD average of 69%, and just 4% reached top performance levels, compared to 9% globally (OECD, 2024).

Educational disparities in Romania are pronounced, with socio-economic background strongly influencing outcomes. The score gap between advantaged and disadvantaged students was 132 points, wider than the OECD average of 93 points. Gender gaps in performance were minimal, with similar proportions of boys and girls classified as low performers (OECD, 2024).

Gender gaps in Mathematics performance are well documented. However, the results are mixed. Guiso et al. (2008), found that in countries with high gender equality (e.g., Sweden, Iceland), girls performed as well as or better than boys in math. In countries with lower gender equality, boys tended to outperform girls, highlighting the impact of cultural factors rather than inherent ability. In their, paper Hyde et al. (2008) conducted a meta-analysis of 7 million students' math scores in the U.S. and have found that gender gaps in overall math performance are negligible. The study concluded that boys and girls are equally capable in math when given equal opportunities.

To our best knowledge, the recent evidence in gender differences in Mathematics performance in the case of the eastern European countries, Romania included are rather scarce. The purpose of the paper is to provide new highlights on the Baccalaureate mathematics performance and to offer insights into the effectiveness of the Romanian education system in preparing students for both academic and professional success. The novelty of the paper is that, by focusing on the mathematics component, this study seeks to uncover trends and disparities in student performance across various profiles and geographical regions, providing a clearer picture of the strengths and challenges faced by the Romanian educational system.

The performance and effectiveness of educational systems related to STEM can be better understood through student achievement on standardized assessments. In Romania, the Baccalaureate exam, an important national test at the end of secondary school, is a significant measure of student learning and preparedness for entering the university level. Nevertheless, the dynamic of the factors that contribute to student performance in the Baccalaureate mathematics component have not been fully investigated.

The Romanian Baccalaureate is a national standardized exam that serves as a gateway to higher education, assessing students' knowledge and competencies at the end of secondary education (high school). The structure of the Baccalaureate exam depends on the educational profile and specialization followed by pupils during their high school years. Regarding mathematics studies, there are four main directions: Mathematics-Informatics, Natural Sciences, Technological, and Pedagogical, each with its own curriculum focus. While each profile covers core subjects such as Romanian Language and a foreign language, the mathematics exam varies significantly depending on the profile. The subjects are tailored to the number of weekly study hours allocated for mathematics in each profile. For example, students in the Mathematics-Informatics profile have a more rigorous mathematics curriculum compared to those in the Technological or Pedagogical profiles, where fewer hours are dedicated to mathematics. Based on this, the level of difficulty varies for each type of exam. Because of the adapted curriculum, the used data is comparable.

Focusing specifically on mathematics as a subject of analysis is highly relevant for several reasons. Firstly, mathematics is a core subject for students in the in the following educational profiles: Mathematics-Informatics, Natural Sciences, and Technological profiles, with varying degrees of difficulty depending on the specialization. Also, mathematics serves as a key indicator of analytical and problem-solving skills, competencies that are critical for success in both higher education and the labour market, especially in science, technology, engineering, and mathematics (STEM) fields. Furthermore, an analysis of mathematics results allows for the identification of patterns in educational achievement, disparities between different profiles, and potential areas for improvement in teaching methodologies.

The research hypotheses are the following:

H1: There are systematic gender gaps regarding mathematics performance in Romanian Baccalaureate exam, between 2017 and 2023.

H2: Educational profile influences mathematics performance.

H3: The interaction between gender and educational profile affects mathematics performance.

This paper brings an analysis of Romanian Baccalaureate mathematics performance by examining gender gaps across the educational profiles over a seven-year period, from 2017 to

2023. Through the application of statistical methods, such as t-tests and General Linear Model, it highlights trends in gender-based performance disparities, offering new insights into the effects of profile specialization on mathematics outcomes. This approach provides a comprehensive view of how educational profiles and socio-economic factors interact with gender to influence academic success, contributing data-driven evidence to the ongoing discourse on equity in education.

2. Literature review

2.1.Evidence on the relation between gender and STEM performance

Research into gender gaps in STEM performance has garnered considerable attention, particularly regarding the discrepancies in mathematics and science outcomes. A substantial body of literature has examined whether boys consistently outperform girls in mathematics or whether these differences are more nuanced.

Ariane Baye et al. (2016) explored the variability in gender differences across various educational contexts and subjects, noting that boys tend to display greater variability in math and science performance, especially at the extremes of the achievement spectrum. This finding supports the "greater male variability hypothesis," which suggests that boys are more likely to be both top and bottom performers in these subjects. However, girls outperform boys on average in reading, demonstrating that gender differences are subject-specific and vary in terms of distribution rather than mean scores alone. Reilly et al. (2015), through a meta-analysis of educational performance, revealed small but consistent differences favoring males, particularly in higher achievers. These gender gaps in high-level mathematics and science achievement contribute to the underrepresentation of women in STEM fields. The study emphasized the need for targeted interventions to close the gender gap and encourage greater female participation in STEM careers. Lindberg et al. (2010) also conducted a meta-analysis on gender gaps in mathematics, analysing over 1.2 million participants. Their findings indicate that, on average, the gender gaps in mathematics performance are minimal, challenging the stereotype that boys are inherently better at math. They found small differences at the higher end of the performance distribution, which slightly favoured males, but overall, the differences were negligible.

Further insights into gender and STEM participation come from Stoet and Geary (2018), who identified the “gender-equality paradox.” They discovered that in countries with higher levels of gender equality, the gaps in STEM participation tend to be larger. Despite girls often outperforming boys in science literacy in these countries, fewer girls choose to pursue STEM-related careers, pointing to complex socio-economic and personal factors that influence career decisions beyond academic performance. Ganley et al. (2016) examined gender gaps in mathematics confidence and interest, concluding that while the performance gap in mathematics is relatively small, differences in confidence and interest are much larger and emerge early in education. They emphasized the importance of early interventions to boost girls' confidence in mathematics, as confidence is a key predictor of future performance and career choices in STEM fields.

2.2 Evidence on Educational Performance in Romania

The existing literature on educational performance highlights the significance of examining changes and developments in standardized test results over time. In Romania, various researchers have focused on factors affecting students' academic outcomes, including socio-economic background, school infrastructure, and regional disparities. Popa (2015) explored how self-regulation and motivation play a crucial role in influencing Romanian students' performance on national exams. The findings suggest that better self-regulated learning skills lead to improved academic outcomes, particularly in subjects like mathematics.

Buza (2024) emphasized geographical and socio-economic disparities in high school performance, using geostatistical methods to analyse Baccalaureate results from 2015 to 2022. The study highlighted that students in urban and economically developed areas perform better compared to their rural counterparts, primarily due to better access to resources. This aligns with the work of Frunzaru (2017), which identified class attendance, gender, parents' education, and social context as strong predictors of high school performance, showing the importance of socio-economic status in shaping educational outcomes.

The research by Muntele et al. (2020) delved into geographical disparities in national assessment success rates, further supporting the idea that students in rural areas face barriers to academic success due to limited educational resources. Similarly, Luț (2020) discussed Romania's need to align its education strategies with EU goals, particularly emphasizing the role of education in sustainable development. The strategic focus on human capital and the gaps identified by Luț highlight broader educational reforms required for long-term progress.

Recent analyses of Baccalaureate mathematics scores by Andrei et al. (2024) used advanced statistical methods like time-series and cluster analysis to explore longitudinal trends in student performance. This research is critical in identifying performance patterns and regional disparities, underscoring the need for more data-driven interventions to improve outcomes. Additionally, Momete (2022) focused on digital education and its role in sustainable development, identifying significant gaps in Romania's formal and non-formal education systems, which prevent it from fully achieving sustainability objectives.

Roman (2021) explored how the pandemic affected educational outcomes, particularly in terms of access to online learning and psychological distress. This study emphasized how remote learning during the pandemic significantly affected Baccalaureate performance, with male students particularly impacted by the transition to eLearning environments. Perța (2024) followed a similar approach, analysing pandemic disruptions in Baccalaureate exam results from 2017 to 2023, noting a decline in success rates and significant gender gaps during the 2020 remote learning period.

3. Data and Methods

This study uses data at individual level on Romanian Baccalaureate mathematics performance from 2017 to 2023. The complete datasets were extracted from data.gov.ro portal, an open data platform that provides publicly accessible information on different areas. The data portal is managed by the Romanian Government and the national education grades are official data provided by the Ministry of Education of Romania. Each database contains personal information at an individual level, with the grades obtained in each assessment, the type of assessment, grades before and after appeals, initial and final averages. From this data, detailed metrics such as mean scores, median scores, quartiles, pass rates and distributions of scores were calculated. The dataset covers multiple educational profiles, including:

- Mathematics-Informatics: The theoretical profile with a focus on mathematics and computer science.
- Natural Sciences: Another theoretical profile with emphasis on biology, chemistry, and physics alongside mathematics.
- Technological: A vocational profile that includes applied mathematics topics relevant to technical fields.
- Pedagogical: A vocational profile focused on teaching and educational studies.

Each year's data has been aggregated at the profile level, allowing for longitudinal comparisons of performance trends across profiles. Additionally, gender-based analyses were conducted to examine performance differences in mathematics between male and female students.

The final database was filtered to include only students who took the mathematics exam as part of the Romanian Baccalaureate, excluding those who took the History exam. Only students who attended all stages of the examination were considered. In preparing the final dataset, students who were absent or disqualified from the exam were excluded to ensure the analysis focused solely on those who fully participated in the Baccalaureate assessments. Variables included in the final analysis are gender, final score at the Mathematics exam, profile, and the type of second exam for each student.

For data visualization and analysis, different tools were used. Tableau software was used to create descriptive statistics, including boxplots, which effectively display the spread and shape of the score distributions. These boxplots help visualize the relationship between the mean and median mathematics scores for each profile. Additionally, Tableau was utilized for the geographical visual analysis, adding another dimension to the data analysis.

IBM SPSS Statistics software version 23 was used to conduct statistical tests, including t-tests and General Linear Models, to examine gender gaps in performance and the interaction effects between gender and educational profiles. In this paper, the General Linear Model

(GLM) was used instead of a traditional ANOVA due to its flexibility in analysing interactions between multiple categorical variables. The GLM enables us to examine the main effects and interaction effects between gender and educational profile on mathematics performance, providing a comprehensive understanding of how these factors jointly influence outcomes. Unlike ANOVA, which is limited to analysing main effects or simple interactions, the GLM framework allows for a more nuanced exploration of the relationships among variables in the model (Field, 2013; Tabachnick & Fidell, 2019). To apply the GLM analysis, specific assumptions were tested to ensure the validity of the results. One key assumption is the homogeneity of variances across groups, which was assessed using Levene's Test for Equality of Variances (Gastwirth et al., 2009). This test revealed significant differences in variances for most years, suggesting some heterogeneity among groups. Despite this, the GLM's ability to accommodate unequal group sizes and manage such variance differences makes it a suitable choice for this analysis (Kutner et al., 2005).

The foundation for the GLM analysis is provided by the next equation:

$$Y = X\beta + \epsilon \quad (1)$$

where:

- Y is the dependent variable (mathematics score);
- X is the matrix of predictors (Gender, Educational Profiles and interactions);
- β represents the coefficients for the predictors;
- ϵ represents the error term, assumed to follow $\epsilon \sim N(0, \sigma^2)$.

Given that the study involves Gender, Educational Profiles and their interactions, the expanded version of the GLM equation is shown in (5).

The assumptions being tested for ensuring the validity and reliability of the results obtained from the GLM are represented by the next equations or expressions:

1. Homoscedasticity (Equal Variance of Residuals) - the variability of residuals is consistent across all levels of the independent variables:
$$Var(\epsilon_i) = \sigma^2, \forall i \quad (2)$$
2. Linearity - the relationship between the dependent variable and the independent variables is accurately captured:
$$\mathbb{E}(Y|X) = X\beta \quad (3)$$
3. Independence of Residuals - the errors are not correlated with each other:
$$Cov(\epsilon_i, \epsilon_j) = 0, \forall i \neq j \quad (4)$$

The following steps were applied in the paper, to conduct a GLM analysis:

1. Data preparation, by filtering out pupils who were absent or eliminated from the exam. This ensured that the analysis only included valid scores for all students who completed the mathematics exam.
2. Selection of variables, focusing on two categorical independent variables: Gender (coded as male and female) and Educational Profile (categorized as Mathematics-

Informatics or MATE-INFO, Natural Sciences or ST-NAT, Technological or TEHN, and Pedagogical or PED). The dependent variable was the Mathematics Score (NOTA_EC).

3. Yearly analysis, since the GLM analysis run separately for each year from 2017 to 2023 to identify any changes in performance over time.
4. Model specification, for each year, with main effects for Gender and Educational Profile, as well as the interaction between Gender and Educational Profile. This allowed assessing not only the independent effects of each variable on mathematics performance, but also how the effect of gender varied across different educational profiles.

For this study, the model equation captures both the main effects of gender and educational profile on mathematics performance, as well as the interaction effect, allowing to explore how gender gaps in mathematics performance may vary across different educational profiles.

To account for the qualitative nature of gender and educational profiles, dummy variables were created and integrated into the analysis. For the gender variable, male students were coded as 0 and female students as 1. For the educational profiles, three dummy variables were created to represent the four profiles. The Mathematics-Informatics profile was treated as the reference category, while the remaining profiles were represented by the dummy variables. Mathematics-Informatics was selected as the reference profile in the GLM because it represents the most mathematics-intensive curriculum, offering the most rigorous preparation in the subject compared to other profiles. This choice provides a baseline for understanding how performance varies in profiles with differing levels of mathematical focus and rigor.

These dummy variables allowed the inclusion of categorical predictors in the GLM, enabling the analysis to assess both the independent and interaction effects of gender and educational profile on mathematics performance. The model quantifies how each educational profile and gender influence performance relative to the reference group.

The marginal effect quantifies the expected change in the dependent variable (mathematics score) resulting from a one-unit change in an independent variable (gender or educational profile), holding other variables constant. In this study, the marginal effect indicates how much a student's mathematics score changes with shifts in factors such as gender or specific educational profiles and indicates how gender differences impact scores within each profile and vice versa. For gender, the marginal effect shows how mathematics performance differs between male and female students, averaging across other variables. For educational profile, it measures how changing the profile (e.g., from Technological to Mathematics-Informatics) impacts the average score, regardless of gender.

4. Results and discussion

4.1.Descriptive statistics

The number of observations for every year 2017-2023 are displayed in Table no.1. The dataset contains the total number of observations for Romanian Baccalaureate participants in mathematics between 2017 and 2023. The number of participants shows fluctuations over the years, with a notable increase in 2020, reaching 109,021, the highest in the period. Following this peak, there is a slight decline in subsequent years, with 79,966 observations recorded in 2022 and a slight increase to 82,055 in 2023.

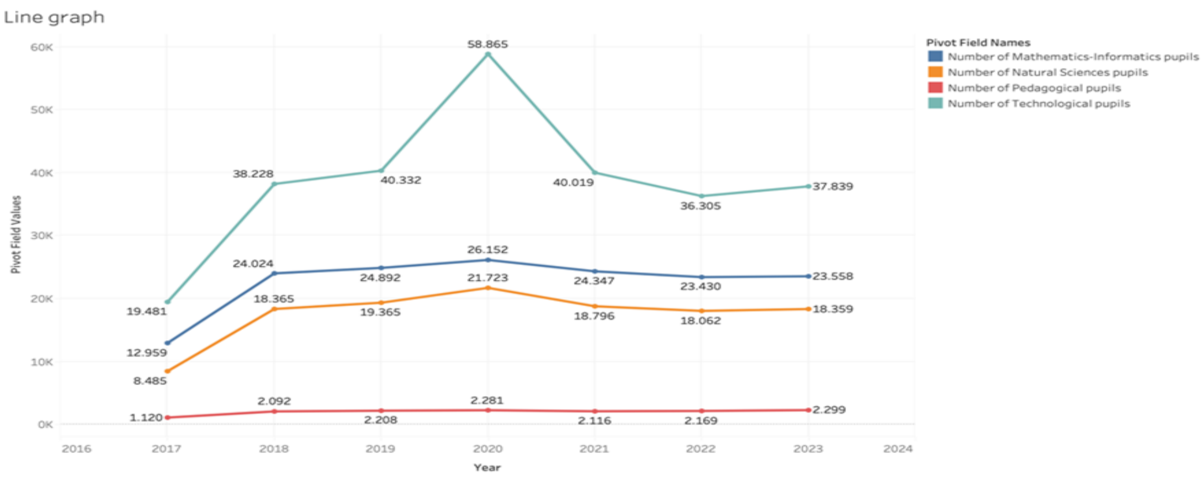
Table no. 1: Total number of observations from 2017-2023

Year	Total number of observations
2017	42045
2018	82709
2019	86797
2020	109021
2021	85278
2022	79966
2023	82055

Source: produced by authors

Figure no.1 shows a line graph for the number of observations from each profile. All profiles show a peak in 2020, followed by a decline in the subsequent years. This peak could be attributed to external factors, possibly related to the impact of the COVID-19 pandemic. The Technological profile has the most significant variations, showing a large peak and subsequent decline. Mathematics-Informatics and Natural Sciences show more stable trends, though they experience a decline post-2020, too. Pedagogical remains the smallest profile but shows slight growth in the recent year (2023), indicating maybe a rising interest in this domain.

Figure no. 1: Number of observations across educational profiles from 2017-2023



Source: produced by authors

The larger number of students in the Technological profile, as compared to the other profiles, can be attributed to its broad range of specializations that cater to diverse practical and vocational interests.

With specializations such as Economics, Mechanical Engineering, Electrical Engineering, Automotive Technology, Tourism and Hospitality, and Agricultural Technology, this profile offers multiple pathways that align with Romania's industrial and service sectors. This diversity attracts more students, as the Technological profile provides hands-on skills and training that are directly applicable to the workforce making it a practical choice for many seeking immediate employment or technical expertise after graduation.

The boxplots from 2017 to 2023 (Figure no. 2) highlight clear trends in mathematics performance across the four educational profiles. Over these seven years, a few key patterns emerge. First, the Mathematics-Informatics profile consistently shows high medians and a more compact distribution of scores, indicating a generally high and consistent performance level across students in this profile.

Figure no. 2: Boxplots for each profile looking at individual years (2017-2019)

Source: produced by authors.

This suggests that the strong mathematics curriculum and focus in this track lead to a relatively uniform achievement among students, with fewer outliers and extremes in performance. The Pedagogical profile, despite not being heavily math-focused, displays surprisingly high performance, with medians surpassing the Mathematics-Informatics track. This may be indicative of a group of pupils who excel due to general academic diligence and the broader focus on pedagogical skills, despite fewer hours dedicated specifically to mathematics. On the other hand, the Natural Sciences and Technological profiles show more variability and lower median scores, especially in the Natural Sciences track. The Technological profile shows a larger range of scores and more significant gaps between the abilities and potentially less effective mathematics preparation in this track, where math is more applied and less theoretically lower quartile and the median. This wider spread suggests a broader spectrum of student rigorous compared to the Mathematics-Informatics track.

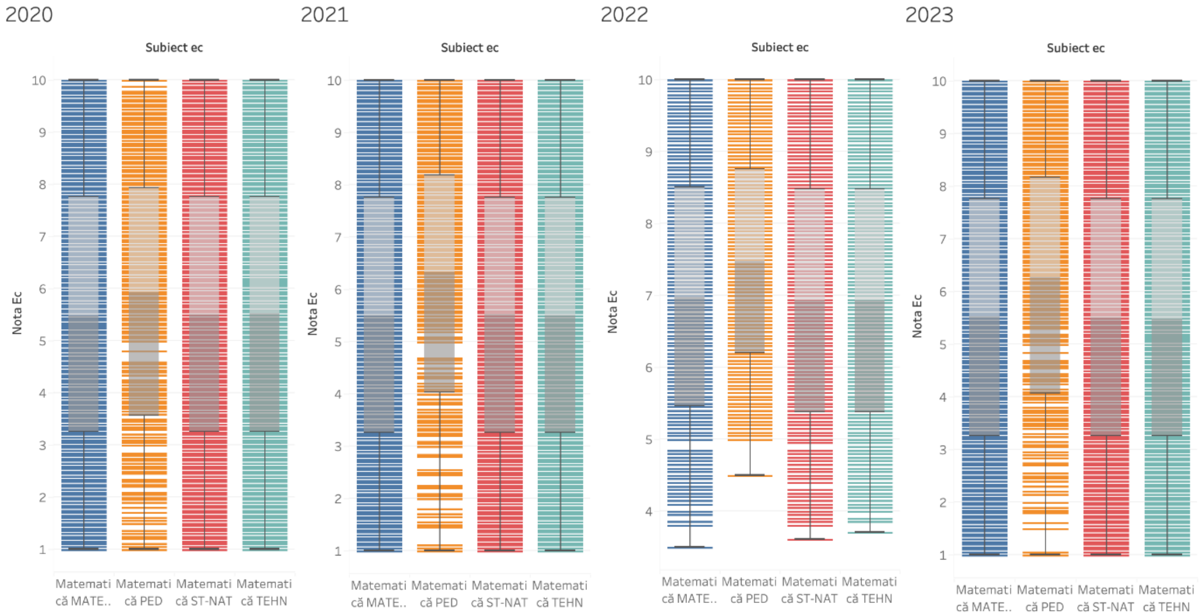


Figure no. 3: Boxplots for each profile looking at individual years (2020-2023)

Source: produced by authors.

4.2. Gender gaps in Mathematics performance

Table no. 2 presents the mean, median, and standard deviation of mathematics scores for male and female students in the Baccalaureate from 2017 to 2023. Every year, female students consistently outperform male students, with higher mean and median scores. The highest mean score for females (7.1608) occurs in 2022, while for males, the peak is slightly earlier, in 2022 as well (6.9377). This indicates that post-pandemic recovery might have been more effective for females.

The standard deviation values for both genders are relatively close across the years, indicating similar levels of variability in performance within each group. However, female students tend to have slightly lower variability, meaning their scores are more concentrated around the mean compared to male students, whose performance is more spread out. Male students exhibit slightly higher standard deviations compared to females in most years, reflecting greater diversity in their performance. Female students' scores are more clustered, as shown by their relatively lower standard deviations.

When the coefficient of variation (CV) is greater than 0.3 (or 30%), it indicates that the series of data is heterogeneous. Overall, both male and female students display the highest variability in performance during 2020, with the CV greater than 0.5. This suggests a disruption in academic consistency, likely influenced by the pandemic. In the next years, the CV for both genders decrease, showing a more uniform performance in 2022 and 2023. The coefficient of variation (CV) highlights significant heterogeneity in scores during the pandemic year of 2020 (CV > 0.5 for both genders), likely due to disruptions in education. A return to lower CV values in 2022 and 2023 (below 0.35) suggests stabilization in academic performance for both genders.

Table no. 2: Gender-Based Descriptive Statistics of Mathematics Baccalaureate Performance in Romania

	Year	2017	2018	2019	2020	2021	2022	2023
Male	Mean	6.6397	5.9860	6.1223	5.0892	6.2034	6.9377	6.7943
	Median	7.1000	6.1000	6.2500	5.4500	6.4000	7.4500	7.1500
	Std. Deviation	2.5860	2.5687	2.5646	3.1580	2.4220	2.3888	2.2843
	Coefficient of variation	0.3894	0.4291	0.4188	0.6205	0.3904	0.3443	0.3362
Female	Mean	7.0393	6.2788	6.4475	5.5946	6.4281	7.1608	7.0163
	Median	7.7500	6.6000	6.8500	6.1000	6.9500	7.9000	7.6000
	Std. Deviation	2.5721	2.6120	2.6109	3.1055	2.4971	2.4578	2.3495
	Coefficient of variation	0.3653	0.4160	0.4049	0.5550	0.3884	0.3432	0.3348

Source: produced by authors

Table no.3 shows the Independent Samples T-Test results for Gender gaps in Mathematics Scores for years 2017-2023. The Levene's Test for equality of variances checks whether the variance of male and female mathematics scores are equal. For most years (except for 2017 and 2020), the Levene’s Test indicates that the variances between male and female scores are significantly different ($p < 0.001$). In 2017 ($p = 0.875$) and 2020 ($p = 0.092$), the non-significant result in the Levene's Test (where $p > 0.05$) implies that the variances in male and female mathematics scores are roughly similar. Some possible reasons for the non-significant Levene’s Test can be the sample consistency, meaning the sample characteristics might have been more consistent across gender groups, leading to similar variability in scores for males and females. As seen in Table no.1 and Figure no.1, in 2017 was the smallest sample size, while in 2020, the biggest. This difference could play a role in the non-significance of Levene's Test in these years due to reduced sensitivity with smaller sample sizes and stabilization of variance in larger samples. In 2017, the smaller sample size may have reduced the test's ability to detect differences in variance, making it less likely to show a statistically significant difference between male and female scores. Small samples often exhibit less statistical power, meaning that even if there were a slight difference in variances, Levene’s Test might not detect it. By contrast, 2020’s large sample size could mean that the scores naturally stabilized in terms of variance between genders. In large samples, individual differences tend to average out, potentially leading to similar variances across groups. This might explain why Levene’s Test found no significant difference in variance between males and females in that year.

The Mean Difference shows how much higher the female scores are compared to the male scores. The negative values indicate that female scores are generally higher than male scores for each year. The magnitude of the difference between male and female scores decreases over time. For example: In 2017, the mean difference was -0.39957, which means female students scored, on average, around 0.40 points higher than male students. By 2023, the difference had decreased to -0.22203, indicating a smaller gap. The 95% Confidence Interval confirms significance since the intervals does not include zero.

Table no. 3: Gender gaps in Mathematics based on Independent Samples T-Test

Year	Levene's Test (F)	Sig. (Levene's Test)	t-value	Sig. (2-tailed)	Mean Difference (Male - Female)	Confidence Interval (95%)
2017	0.025	0.875	-15.881	0.000	-0.39957	(-0.44889, -0.35026)
2018	58.622	0.000	-16.245	0.000	-0.29274	(-0.32807, -0.25742)
2019	71.565	0.000	-18.507	0.000	-0.32517	(-0.35960, -0.29073)
2020	2.833	0.092	-26.627	0.000	-0.50543	(-0.54264, -0.46823)
2021	110.126	0.000	-13.340	0.000	-0.22471	(-0.25773, -0.19170)
2022	48.319	0.000	-13.012	0.000	-0.22301	(-0.25660, -0.18942)
2023	68.417	0.000	-13.725	0.000	-0.22203	(-0.25374, -0.19033)

Source: produced by authors

4.3. General Linear Model

The General Linear Model (GLM) analyses were conducted in SPSS using gender and educational profile as fixed factors, with mathematics score as the dependent variable. The analysis included the main effects of gender and educational profile, as well as their interaction term to assess whether the effect of gender on mathematics performance varied across profiles. Yearly analyses were performed by specifying a separate GLM for each year from 2017 to 2023.

The general equation for the GLM is:

$$Y = \beta_0 + \beta_1 X_{\text{Gender}} + \beta_2 D_1 + \beta_3 D_2 + \beta_4 D_3 + \beta_5 (X_{\text{Gender}} \times D_1) + \beta_6 (X_{\text{Gender}} \times D_2) + \beta_7 (X_{\text{Gender}} \times D_3) + \epsilon \quad (5)$$

where:

- Y is the dependent variable (mathematics score);
- β_0 is the average mathematics score for the reference category (male students in the Mathematics-Informatics profile);
- β_1 is the effect of being female (relative to male) in the reference profile (Mathematics-Informatics);
- $\beta_2, \beta_3, \beta_4$ are the differences in performance for profiles D_1, D_2, D_3 (relative to the reference profile, Mathematics-Informatics);
- $\beta_5, \beta_6, \beta_7$ are the differences in gender effects across the respective profiles. They show how the gap between male and female scores changes depending on the profile;

- D_1, D_2, D_3 are dummy variables representing the exam type (D_1 for Natural Sciences, D_2 for Technological, D_3 for Pedagogical);
- $X_{\text{Gender}} \times D_1$ is the interaction between gender and the Natural Sciences profile;
- $X_{\text{Gender}} \times D_2$ is the interaction between gender and the Technological profile;
- $X_{\text{Gender}} \times D_3$ is the interaction between gender and the Pedagogical profile;
- ϵ represents the error term.

Table no.4 provides a summary of the General Linear Model results analyzing the effects of gender, subject type, and their interaction on mathematics performance for each year. For every year, the F-values for gender are statistically significant ($p < 0.001$), showing that there are consistent differences in mathematics performance between male and female students. The F-statistics fluctuate, suggesting variability in the magnitude of gender effects year-to-year, with the strongest effect observed in 2019 ($F = 30.381$) and the weakest in 2022 ($F = 10.719$). Performance differences among students in the Natural Sciences profile are highly significant ($p < .001$) every year, with F-statistics peaking in 2021 ($F = 3026.621$). The Technological profile exhibits the most substantial and consistently significant differences ($p < .001$), with extremely high F-statistics, particularly in 2019 ($F = 30{,}730$). For the Pedagogical profile, differences are generally non-significant (e.g., $p = 0.823$ in 2017 and $p = 0.995$ in 2022). However, in 2019 and 2020, significant effects emerge ($p = 0.027$ and $p = 0.022$), though the F-values are much smaller than for the other profiles, showing minimal variability in this group. For the interaction effects, the interactions between Gender and Natural Sciences and Gender and Technological were statistically significant for most years. This evidence clearly suggests that the gender gap in mathematics performance varies significantly depending on the educational profile. This confirm the second research hypothesis of this study (H2).

Table no. 4: Summary of the General Linear Model (Univariate) Analysis for Gender, Subject Type, and Their Interaction on Mathematics Performance

Variable	2017	2018	2019	2020	2021	2022	2023
Gender (main effect)	F=23 p<.001	F=19 p<.001	F=30 p<.001	F=13.6 p<.001	F=11.311 p<.001	F= 10.719 p<.001	F=25.340 p<.001
Natural Sciences (D1)	F=236 p<.001	F=567 p<.001	F=2135 p<.001	F=1528 p<.001	F=3026 p<.001	F= 208 p<.001	F=356 p<.001
Technological (D2)	F=7969 p<.001	F=20379 p<.001	F=30730 p<.001	F= 19172 p<.001	F=16352 p<.001	F= 9674 p<.001	F=12046 p<.001
Pedagogical (D3)	F=.050 p=.823	F=3.426 p=.064	F=4.87 p=.027	F=5.216 p=.022	F=2.031 p=.154	F=.000 p=.995	F=3.206 p=.073
Gender × D1 Interaction	F=23 p<.001	F=6.878 p<.001	F=12.267 p<.001	F=20.291 p<.001	F=24.901 p<.001	F=0.171 p=.679	F=17.487 p<.001
Gender × D2 Interaction	F=0.116 p=.733	F=49.199 p<.001	F=36.492 p<.001	F=14.227 p<.001	F=38.342 p<.001	F=53.363 p<.001	F=21.886 p<.001
Gender × D3 Interaction	F=3.851 p=.050	F=3.006 p=.083	F=4.136 p=.042	F=.088 p=.767	F=0.302 p=.583	F=.199 p=.656	F=8.469 p=.004

Source: produced by authors.

Significant main effects and interactions during 2020 reflect disruptions in education. Gender × Profile interactions are notably significant in this year for Natural Sciences and

Technological, highlighting that the pandemic may have exacerbated performance gaps depending on gender and profile. From 2021 to 2023, F-values for interaction effects show some decline, suggesting a gradual stabilization in gender and profile-based performance disparities as education systems adjusted to post-pandemic conditions.

The marginal effect of gender on mathematics performance shows that, on average, female students score higher than male students across all educational profiles. Also, the marginal effect of educational profile reveals that students in the Pedagogical profile outperform those in Technological and Natural Sciences profiles, emphasizing the critical role of curriculum's structure and focus in shaping academic outcomes. The results from the GLM models confirm the third research hypothesis (H3), revealing the role of the educational.

4.4. Geographical visual analysis

The maps (Figure no. 4 and Figure no. 5) show the average mathematics scores for female and male students in Romania in 2023, broken down by county.

For the female filtered map, counties such as Suceava, Iași, Cluj, and Botoșani demonstrate higher average scores, with averages close to or above 7.0. Conversely, counties like Teleorman, Mehedinți, Ilfov and Călărași show the lowest female performances, with average scores as low as 5.444 in Teleorman.

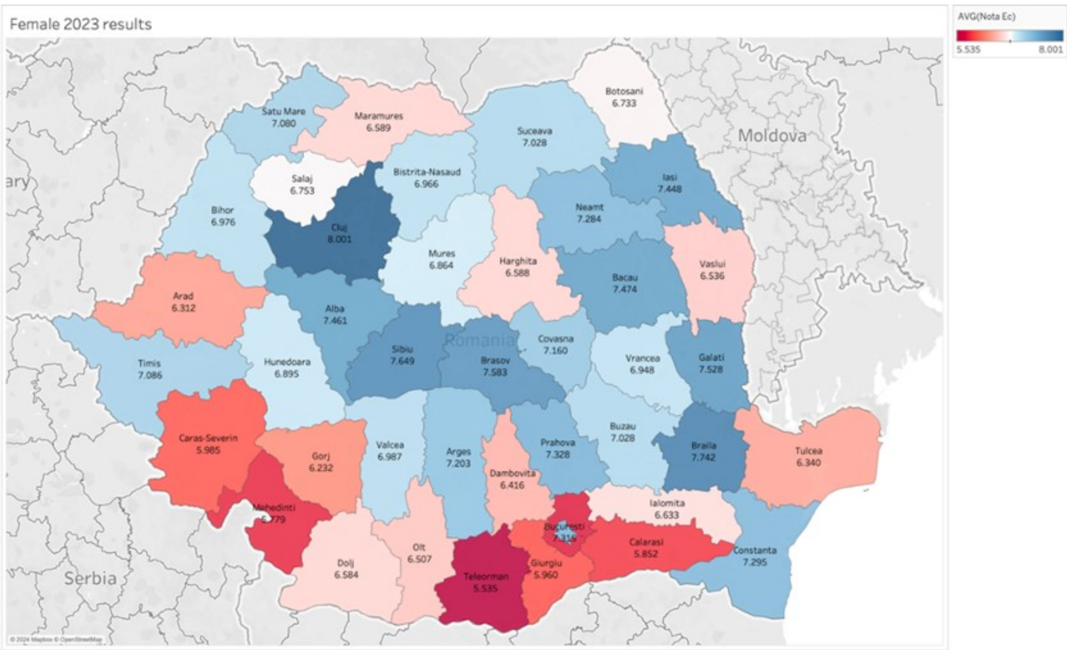


Figure no. 4: Geographical Counties Distribution of Romanian Baccalaureate Mathematics Results by Females in year 2023

Source: produced by authors.

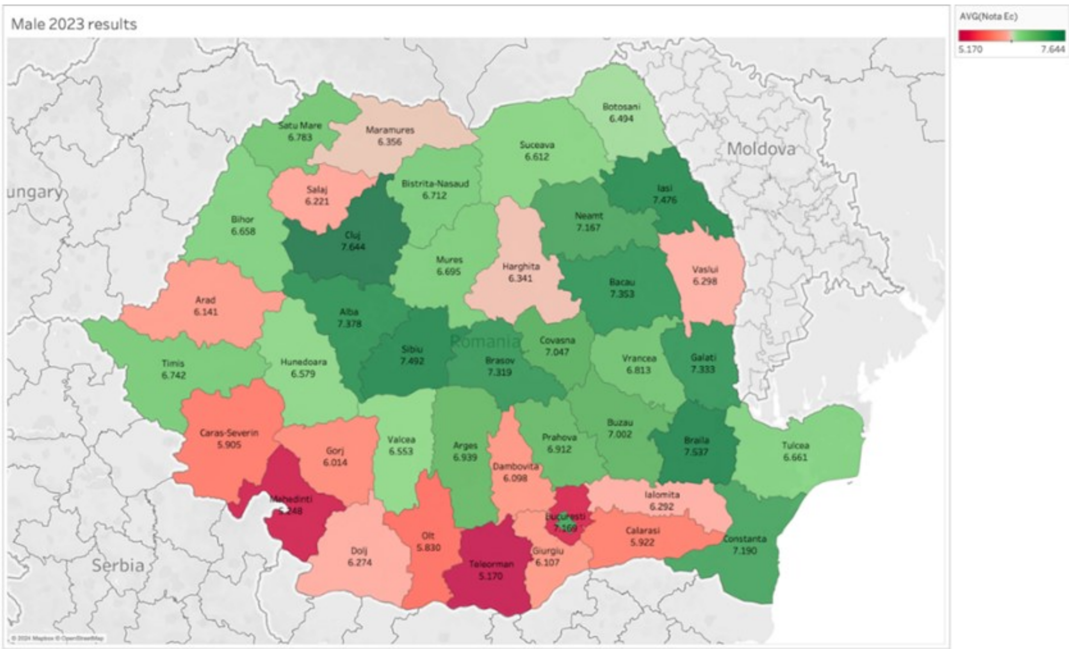


Figure no. 5: Geographical Counties Distribution of Romanian Baccalaureate Mathematics Results by Males in year 2023

Source: produced by authors

The distribution for male students shows a similar geographical pattern, although the average scores are generally lower. Counties like Cluj, Brăila, Sibiu and Iași perform relatively better for male students, with averages around 7.5. Teleorman, Ilfov, Călărași and Mehedinți again show lower results for male students, similar to the female results, but the scores are even lower, particularly in Teleorman, which shows an average of 5.170 for male students. The disparity between higher and lower-performing counties is more pronounced for male students, with some counties showing lower performance levels overall compared to females. These maps suggest that location and possibly regional resources have a notable impact on educational outcomes, reinforcing the need for targeted interventions in underperforming areas. The observed pattern suggests a geographic trend, where northern and central Romania tend to have better average scores, while southern and some eastern counties struggle more with performance. The colour distribution helps visualize the regional disparities clearly and indicates areas that might require more educational support and resources. This pattern remains consistent with the geographic distribution observed in 2022 (Figure no. A1 and Figure no. A2 in Appendix), reinforcing the idea that these disparities are persistent over time.

5. Discussion

The discussion section begins with the evaluation of the three central hypotheses that guided this analysis.

H1: There are systematic gender gaps regarding mathematics performance in Romanian Baccalaureate exam, between 2017 and 2023.

The first hypothesis explored whether gender differences significantly affect mathematics performance in the Baccalaureate exams. Across all seven years, female students consistently outperformed male students, as indicated by higher mean and median scores. The results of the independent t-tests further supported this finding, showing that the mean differences between male and female students were statistically significant ($p < 0.05$) for all years. This trend indicates a consistent advantage for female students in mathematics performance, despite the common assumption that males may excel in this subject area. The significant t-values across all years confirm the robustness of these gender gaps. Overall, females perform better at the Baccalaureate exam, according to Perța (2024), and mathematics makes no exception from this.

H2: Educational profile influences mathematics performance.

The second hypothesis tested whether students' educational profiles significantly influence their mathematics performance. The analysis revealed notable differences in mathematics scores between students in the four profiles. Across all seven years, students in the Pedagogical profile consistently outperformed students in other profiles, with the profile Mathematics-Informatics also showing strong results. The results of the General Linear Model tests for each year showed that educational profile had a statistically significant effect on mathematics performance This pattern persisted in all years, with the Pedagogical profile showing the highest performance, followed by Mathematics-Informatics, Natural Sciences, and Technological. These results suggest that the level of focus on mathematics within each educational track is a crucial factor driving students' performance in the Baccalaureate exams.

H3: The interaction between gender and educational profile affects performance outcomes.

The third hypothesis investigated the interaction effect between gender and educational profile on mathematics performance. The results showed a statistically significant interaction between these two factors, indicating that the impact of gender on mathematics performance varied depending on the educational profile. The General Linear Model results for the interaction between gender and profile were significant for all years ($p < 0.05$). The interaction plots further illustrated this effect, showing that while female students generally outperformed male students across all profiles, the magnitude of this difference varied. For example, in the Mathematics-Informatics profile, the gap between male and female students was smaller compared to the Technological profile, where female students had a notably higher advantage. This finding suggests that gender gaps in performance are more pronounced in profiles with less focus on mathematics, such as the Technological and Pedagogical tracks, whereas in more mathematics-intensive profiles, such as Mathematics-Informatics, the gap is narrower.

Our findings align with existing literature on gender differences in high school mathematics performance. In many countries, male students have historically outperformed female students in mathematics. However, recent analyses suggest that this trend is changing, with the gap narrowing or even reversing in certain contexts. For instance, research indicates that in educational systems that promote gender equality and provide supportive learning conditions, female students often achieve higher mathematics scores than their male counterparts (Ghasemi et al., 2019). This shift underscores the evolving dynamics of gender disparities in mathematics performance.

Additionally, our analysis supports previous research that highlights the significant impact of educational profiles on mathematics achievement. Curricular emphases and teaching methodologies across educational tracks play a critical role in shaping outcomes. Students enrolled in science-oriented programs, such as Mathematics-Informatics or Natural Sciences, often demonstrate higher proficiency in mathematics compared to those in profiles with less mathematical emphasis, such as Technological or Pedagogical tracks (Liu et al., 2024). This finding underscores the importance of curriculum design and its alignment with the specific needs of students to optimize performance.

Furthermore, our study highlights the interaction between gender and educational profiles, which emerges as a critical factor influencing mathematics performance. Consistent with existing literature, gender disparities in mathematics vary significantly across educational settings. In some cases, female students in science-intensive programs outperform their male peers, while in other contexts, traditional gender gaps persist (Ellison & Swanson, 2023). This variability highlights the necessity of addressing gender disparities within specific educational contexts, taking into account the curriculum, teaching approaches, and broader systemic factors.

By situating our findings within this broader research context, we contribute to understanding of how gender and educational profiles interact to influence mathematics performance. These insights are particularly relevant in the Romanian educational landscape, where the observed variations reflect both global trends and local particularities.

This study has limitations that should be noted. The reliance on aggregate data restricts the exploration of individual-level factors, such as socioeconomic or psychological influences on performance. The analysis focuses only on Romanian Baccalaureate mathematics results from 2017 to 2023, limiting generalizability to other contexts or timeframes. Additionally, the absence of qualitative data and reliance on statistical models like the GLM may not fully capture the complexity of performance disparities. Future research should incorporate more detailed datasets and mixed methods for a deeper understanding.

The paper also opens the room for further research. It suggests that there are several factors behind the gender and specializations that worth being explored. However, the data reported by the schools and authorities in the field of education in the context of national evaluations only, does not allow for deeper analysis. The paper suggests that it would be crucial to collect micro data and to conduct dedicated research at national level, for understanding the crucial role of economic or social factors. Future research integrating microdata could offer a more comprehensive view of how economic, social, and educational influences intersect, paving the way for evidence-based policy interventions.

6. Conclusions

This study explored gender gaps and educational profile influences on Romanian Baccalaureate mathematics performance over the years 2017 to 2023. Using data from various profiles, Mathematics-Informatics, Natural Sciences, Technological, and Pedagogical, the analysis uncovered significant patterns and variations across both gender and profile type.

This study examined three key ideas: gender differences in mathematics performance, the influence of educational profiles, and the interaction between gender and profile. Results revealed that female students outperformed male students, especially in the Pedagogical and Natural Sciences profiles. Furthermore, students' educational profiles significantly impacted their performance, with Pedagogical students achieving the highest scores. Lastly, the interaction between gender and profile indicated that gender gaps in performance vary by educational track.

The findings from this study confirm that gender and educational profile both play significant roles in shaping mathematics performance in Romania's Baccalaureate exams. Female students consistently perform better than male students across all profiles, with the Pedagogical and Mathematics-Informatics profiles producing the highest scores overall. One possible explanation for why female students achieve better results than males could be that, due to Romania's rather rigid educational system, girls tend to be more conscientious and obedient. Also, one possible reason for females outperforming males in mathematics could be their greater motivation to achieve academic success as a pathway to independence and securing well-paying jobs. This drive may stem from a desire to ensure financial stability and autonomy, especially in a competitive and evolving job market.

However, in profiles where mathematics holds a more significant place in the curriculum, boys tend to perform better compared to boys in the other profiles. This suggests that the curriculum's structure and emphasis on mathematics significantly influence performance differences across gender and educational paths.

The interaction between gender and profile indicates that the performance gap between male and female students is not uniform, but varies depending on the educational track, highlighting the importance of contextualizing gender gaps within the broader educational framework. Over the years, there are some observable improvements in the performance, particularly in 2020 and onwards. This may reflect a gradual adjustment in education strategies post-pandemic, with students and teachers adapting to new learning environments and methodologies. These findings make a significant contribution to understanding how gender, educational profiles, and curriculum structure influence academic outcomes, providing valuable insights into persistent disparities in Romanian education. The performance variations across profiles underscore the need for tailored interventions to support students in underperforming tracks, particularly those in the Technological profile. Focused efforts, such as additional resources, adaptive teaching methods, and targeted programs, could address the unique challenges faced by these students and contribute to a more equitable educational system.

The geographic analysis of Baccalaureate mathematics performance reveals significant regional disparities in Romania, with clear differences between counties. Northern and central regions consistently display stronger performance, while southern counties struggle with lower average scores. This regional divide is observed for both male and female students, though the gender gap remains evident across all areas. These results highlight the need for targeted educational interventions in underperforming regions, particularly in the south, where socioeconomic factors may be contributing to weaker outcomes. Addressing these geographical disparities could help bridge the performance gap and promote more equitable access to quality education throughout the country. Overall, the study underscores the need for targeted educational strategies that address both gender and profile-specific factors to ensure equitable mathematics performance for all students.

References

Andrei, T., Mirica, A. and Stoica, I.-E. (2024). National Examination in Romania between 2017 and 2023 – A Microdata Analysis. *Proceedings of the 7th International Conference on Economics and Social Sciences*. doi:https://doi.org/10.24818/icess/2024/035.

Baye, A. and Monseur, C. (2016). Gender differences in variability and extreme scores in an international context. *Large-scale Assessments in Education*, 4(1). doi:https://doi.org/10.1186/s40536-015-0015-x.

Buza, V. and Tușa, E. (2024). Disparities in School Performance in Romania. A Geostatistical Analysis of Baccalaureate Results between 2015-2022. *Revista Romaneasca pentru Educatie Multidimensionala*, [online] 16(1), pp.391–428. doi:https://doi.org/10.18662/rrem/16.1/829.

Ellison, G., & Swanson, A. (2023). Dynamics of the Gender Gap in High Math Achievement. *Journal of Human Resources*, 58(5), 1679–1711. https://doi.org/10.3368/jhr.58.5.0620-10972r1.

Field, A. (2013). *Discovering statistics using IBM SPSS statistics* (5th ed.). Sage Publications.

Frunzaru, V. (2017). *High school pupils' performance in Romania: individual and social predictors*. Revista română de sociologie, pp.227–247.

Ganley, C.M. and Lubienski, S.T. (2016). Mathematics confidence, interest, and performance: Examining gender patterns and reciprocal relations. *Learning and Individual Differences*, [online] 47, pp.182–193. doi:https://doi.org/10.1016/j.lindif.2016.01.002.

Gastwirth, J. L., Gel, Y. R., & Miao, W. (2009). The Impact of Levene's Test of Equality of Variances on Statistical Theory and Practice. *Statistical Science*, 24(3), 343–360. https://doi.org/10.1214/09-sts301.

Ghasemi, E., Burley, H., & Safadel, P. (2019). Gender Differences in General Achievement in Mathematics: An International Study. *New Waves Educational Research & Development*, 22(1), 27–54.

Guiso L, Monte F, Sapienza P, Zingales L. (2008) Diversity. Culture, gender, and math. *Science.* 320(5880):1164-5. doi: 10.1126/science.1154094. PMID: 18511674.

Hyde JS, Lindberg SM, Linn MC, Ellis AB, Williams CC. Diversity. Gender similarities characterize math performance. *Science.*; 321(5888):494-5. doi: 10.1126/science.1160364. PMID: 18653867.

Ionescu, C.V. (2018). Predictors of the performance at the Baccalaureate in Romania. A Pilot Study. *Studia Doctoralia*. Psychology and Educational Science, 16, pp.77–86.

Kutner, M. H., Nachtsheim, C. J., Neter, J., & Li, W. (2005). *Applied linear statistical models*. Mcgraw-Hill Education.Lindberg, S.M., Hyde, J.S., Petersen, J.L. and Linn, M.C. (2010). New trends in gender and mathematics performance: A meta-analysis. *Psychological Bulletin*, [online] 136(6), pp.1123–1135. doi:https://doi.org/10.1037/a0021276.

Liu, X., Hansen, K. Y., Valcke, M. et al (2024). A decade of PISA: student perceived instructional quality and mathematics achievement across European countries. *ZDM Mathematics Education*, 56, 859–891. https://doi.org/10.1007/s11858-024-01630-7

Luț, D.M. (2020). The analysis of Romanian education and training system in accordance with European requirements. *Quaestus Multidisciplinary Research Journal*, pp.173–184.

McPherson, M.A., Jewell, R.T. and Kim, M. (2009). What determines student evaluation scores? A random effects analysis of undergraduate economics classes. *Eastern economic journal,* 35(1), pp. 37–51.

Miller, J. & Haden, P., 2024. *Statistical Analysis with The General Linear Model*. Open Educational Resource (OER) - USK Library. Available at: (http://uilis.usk.ac.id/oer/items/show/327) [Accessed 6 Nov. 2024].

Mirică, A., Ceban, O. and Petcu, I.-R. (2023). Students' performance at the Baccalaureate Exam during the COVID-19 pandemic – Evidence from Romania. *Communications of International Proceedings*, [online] 3. Available at: https://ibimapublishing.com/p-articles/COVID40EDU/2022/3942522/.

Momete, M.M. and Momete, D.C. (2022). Investigation of the Performance of Education for Sustainable Development in Romania. *Journal of e-Learning and Higher Education*. [online] doi:https://doi.org/10.5171/2022.156428.

Muntele, I., Istrate, M. and Bunduc, F. (2020). Educational disparities in Romania. A multilevel analysis of the national assessment examination succes rate educational disparities in Romania. A multilevel analysis of the national assessment examination succes rate. *Rom. Journ. Geogr.*, 64(1), pp.43–55.

Nota, L., Soresi, S. and Zimmerman, B.J. (2004). Self-regulation and academic achievement and resilience: A longitudinal study. *International Journal of Educational Research*, 41(3), pp.198–215. doi:https://doi.org/10.1016/j.ijer.2005.07.001.

OECD. 2024. Education at a glance, online report, available at: https://www.oecd.org/en/publications/education-at-a-glance-2024-country-notes_fab77ef0-en/romania_50189b64-en.html, [Accessed 20 November 2024]

Popa, D. (2015). The Relationship Between Self-Regulation, Motivation And Performance At Secondary School Students. *Procedia - Social and Behavioral Sciences*, 191(191), pp.2549–2553. doi:https://doi.org/10.1016/j.sbspro.2015.04.410.

Reilly, D., Neumann, D.L. and Andrews, G. (2015). Sex differences in mathematics and science achievement: A meta-analysis of National Assessment of Educational Progress assessments. *Journal of Educational Psychology*, 107(3), pp.645–662. doi:https://doi.org/10.1037/edu0000012.

Roman, M., Plopeanu, A.P. (2021). The effectiveness of the emergency eLearning during COVID-19 pandemic. The case of higher education in economics in Romania. *International Review of Economics Education*, *37*, 100218.

Stoet, G. and Geary, D.C. (2018). The Gender-Equality Paradox in Science, Technology, Engineering, and Mathematics Education. *Psychological Science*, 29(4), pp.581–593.

Tabachnick, B. G., & Fidell, L. S. (2019). *Using multivariate statistics* (7th ed.). Pearson Education Limited.

Urean, C.A. (2017). An overview of the Romanian education system. *Annals - Economy Series*, 1(3), pp.146–153.

U.S. Bureau of Labor Statistics. (2024, August 29). *Employment in STEM occupations: U.S. Bureau of Labor Statistics*. Bls.gov; U.S. Bureau of Labor Statistics. https://www.bls.gov/emp/tables/stem-employment.htm

Appendix

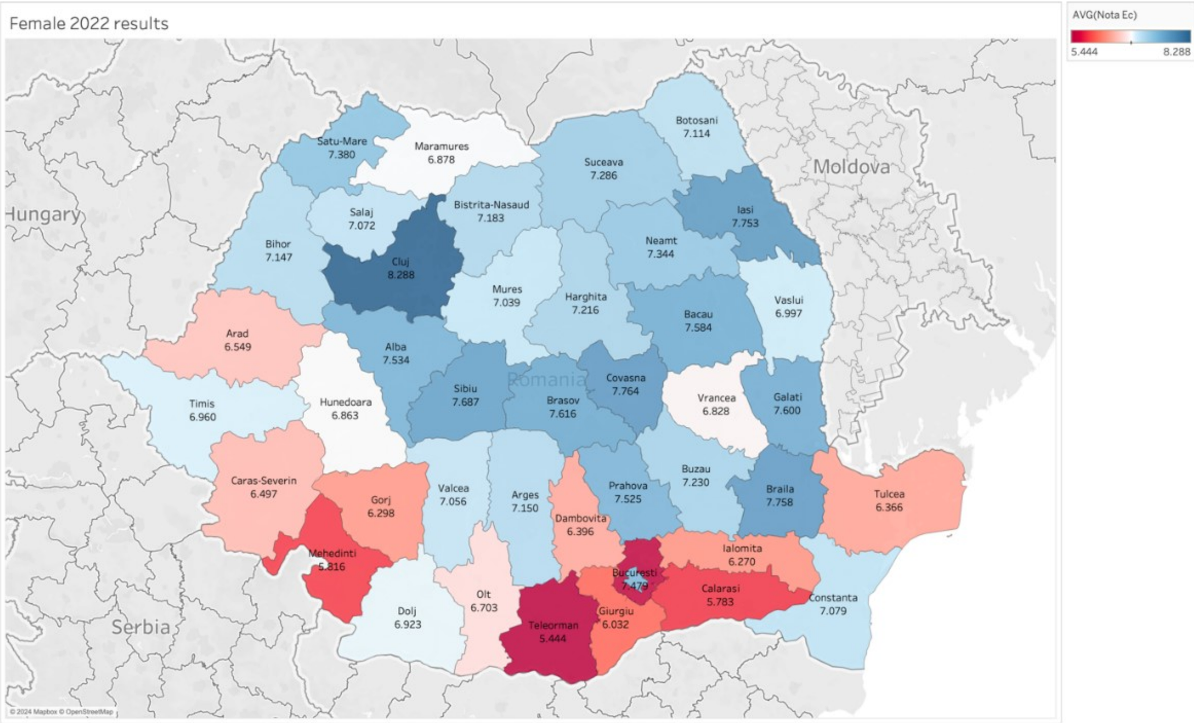


Figure no. A1: Geographical Counties Distribution of Romanian Baccalaureate Mathematics Results by Females in year 2022

Source: produced by authors

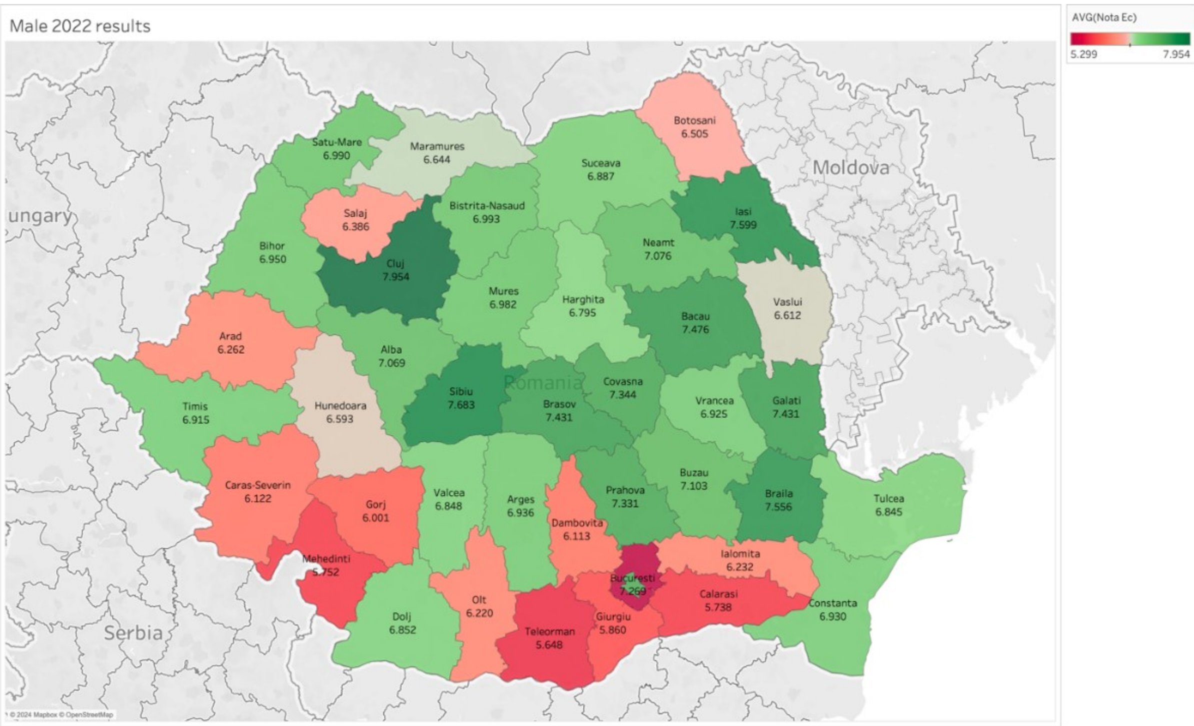


Figure no. A2: Geographical Counties Distribution of Romanian Baccalaureate Mathematics Results by Males in year 2022

Source: produced by authors