ISTITUTO NAZIONALE PER L'ANALISI DELLE POLITICHE PUBBLICHE

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THE MATH GENDER GAP IN ITALY AND POLAND: EMPIRICAL EVIDENCE FROM PISA DATA

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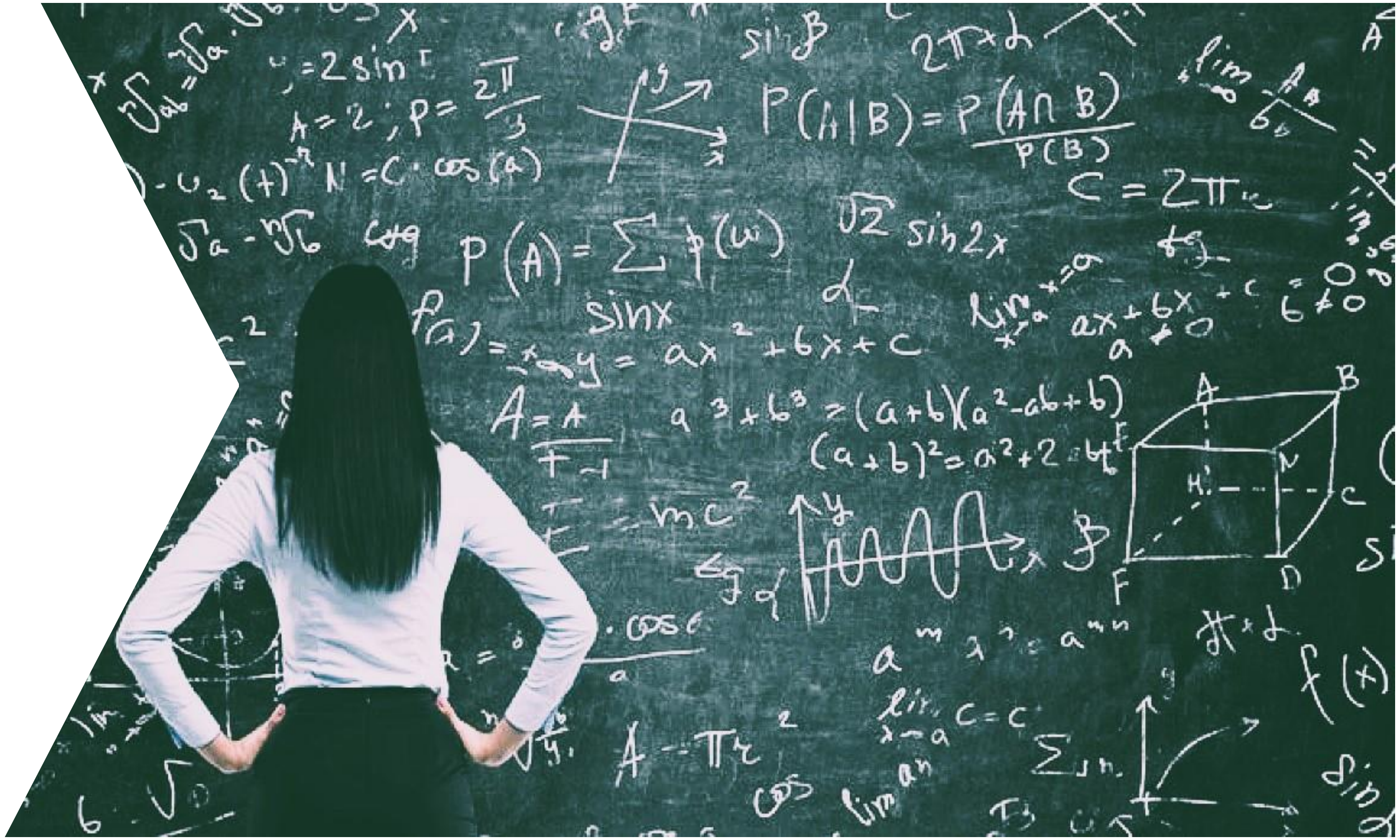
CONTENTS



INTRODUCTION

Significant gender gaps in mathematics achievement for boys are found internationally, with wide variations between countries (Zhou, 2017; Ellison, 2018; Mullis et al., 2020).

The gender gap in mathematics also has repercussions on the lower propensity of women to choose university and professional study paths with a scientific or STEM (Science, Technology, Engineering and Mathematics) focus, which are more requested and remunerated by the labor market (Rosti, 2006; Barone , 2020).

The results of the OECD's PISA (Programme for International Student Assessment) international survey have shown since the first edition in 2000 that boys perform better than girls in mathematics, but worse in reading, with some variability between countries (Di Castro, Ferri, 2022).

In particular, **it emerges that Italy has one of the highest gaps analyzed in the PISA tests, while Poland has a gender gap in mathematics close to zero, while in Italy it is very high**.

LITERATURE

SOME STUDIES THAT HAVE INVESTIGATED THE FACTORS UNDERLYING THE GAP IN MATHEMATICS

- Biological explanations (Kimura, 2000)
- Explanations that involve the influence of social and cultural factors (Guiso 2008; Li 1999)
- Contextual and psychological factors(Gunderson, 2012).
- Deep-rooted stereotypes - in teachers, parents, etc. - or implicit Bias (Avitzour *et al.* 2020; Copur-Gencturk *et al.* 2020)
- Learning strategies, attitudes, motivation, anxiety, which seem to manifest in a different between the male and female (OECD, 2015)

THE ROLE OF CONTEXT

- Many researchers agree that some school context variables hinder students' academic performance.

- Smaller schools would contribute positively to student achievement (Fidler 2001; Leithwood and Jantzi 2009)

- Studies in the United Kingdom have shown that infrastructure explains 16% of the variation in the academic performance of primary school students (Teixeira et al., 2017).

- Technological equipment is also of fundamental importance: moderate use of computers in the classroom tended to favor learning outcomes; negative results for more intensive use (OECD 2015)

METHODOLOGY

- The Oaxaca-Blinder decomposition method (Blinder, 1973; Oaxaca, 1973; Jann, 2008).
- Through this method, it is possible to distinguish the part of the differences due to the characteristics included in the model estimates and the part that remains unexplained.
- First, the average differences in results between the two groups are calculated, then the difference is broken down into two parts.
- The explained part (endowment effect) is attributed to differences in the characteristics of the two groups (such as education, work experience, age, etc.), while the other unexplainable part (coefficient effect), is attributed to factors not explained by differences in characteristics, which can be defined as "discrimination". Our target group is women.

FORMULA

$$E = \{E(X_{NI}) - E(X_{I})\}\ \beta_{NI}$$

$$C=E(X_{NI})(\beta_{NI}-\beta_{I})$$

$$I=\{E(X_{NI})-E(X_{I})\}(\beta_{NI}-\beta_{I}))$$

$$R = \{E(X_{NI)} - E(X_{I})\}\ \beta_{NI}+ E(X_{NI})\ (\beta_{NI} - \beta_{I}) + \{E(X_{NI}) - E(X_{I})\}\ (\beta_{NI}-\beta_{I})$$

- Following Fortin, Lemieux and Firpo (FLF) we apply the decomposition by calculating the RIF (Recent Influence Function) regressions in order to observe the scoring results along the distribution (Fortin *et al*., 2011).
- This advanced technique allows to provide robust estimates, and is used to estimate the impact of an independent variable on a dependent variable, taking into account the presence of unobserved heterogeneity. By applying the Oaxaca-RIF method on percentiles, it is possible to observe the changes in the effects of independent variables depending on the position in the distribution of the dependent variable (PISA scores in mathematics).

To this end, on the basis of the above-mentioned literature, among the many information available thanks to PISA data, some variables relating **to both school context factors, such as class size, have been selected** (Blackmore *et al*., 2011; Brühwiler and Blatchford, 2011), **both in the family context, such as the language spoken at home** (Di Castro *et al.,* 2023), and **variables related to the territorial context** (Echazarra and Radinger, 2019) such as the number of inhabitants of the center where the school is located. Some variables relating to **individual factors** (competitiveness, motivation, commitment, goal orientation, etc.) have also been included, measured on the basis of the self-assessments that students make in a special section of the questionnaire.

-In the model, through the **merge of the data-sets**, the variables related to the school, deriving from the PISA OECD questionnaire addressed to school leaders, are added. In fact, through this enrichment of information, it is possible to take into account how the variables relating to the school context of reference (infrastructure, educational offer, extra-curricular offer, teachers, etc., see Table 1) affect the differences in results between the two groups.

-We compare Italy and Poland to investigate why, while in Italy the differences between males and females in mathematics in PISA scores are particularly evident.

- In Poland, this gap, thanks also to some policies implemented in recent years, has progressively narrowed to the point of being statistically insignificant, as will be seen in more detail in subsequent analyses.

VARIABLES INCLUDED IN ESTIMATES
SOURCE: INAPP ELABORATIONS ON PISA 2018 DATA

Private school	**1=private school; 0=otherwise**
School type	Type of secondary school
Teacher shortage	1= Shortage of teachers in the school to which they belong; 0=otherwise
Lack of teaching materials	1=Lack of teaching materials in the school to which they belong; 0=otherwise
Lack of infrastructure	1= Lack of infrastructure in the school to which they belong; 0=otherwise
Internet bandwidth at school	1=Sufficient bandwidth and internet connection speed at school; 0=otherwise
Teacher Refresher Courses	Teacher update 1=yes, 2=no
Students per class <15	Number of students per class including <15
Students per class (16-20)	No. of students per class between 16 and 20
Students per class (21-25)	No. of students per class between 21 and 25
Students per class (26-30)	No. of students per class between 26 and 30
Students per class >31	No. of students per class between 31 and 35
Additional Italian lessons	1=Realization of additional Italian language lessons; 0=otherwise
Competitiveness	Student Competitiveness

Goal Orientation	Goal Orientation
Motivation	Motivation, commitment
Positive disciplinary climate	Positive disciplinary climate (in Italian lessons)
Italian language spoken at home	Language spoken at home by the student: 1= of the host country; 0=Source language
Repeating	Repeating student (one or more times)
Inhabitants <15000	Inhabitants <15000=0
Average number of inhabitants	Population 15,000-1,000,000
Number of inhabitants > million	Population >1,000,000
Teacher Skills	1= Adequate skills of the teaching staff in the school to which they belong (as assessed by the DS); 0=otherwise
Equal educational offer in the area	Schools of the same type in the area
Italian Language Preparatory Course	Italian Language Preparatory Course
Escs	PISA index of economic, social and cultural status.
Resilience	Resilience, self-efficacy
Sense of belonging	Sense of belonging to the school
Failure	Fear of failure
Age	Age of the individual
Immigrate	Immigrant

MAIN FINDINGS

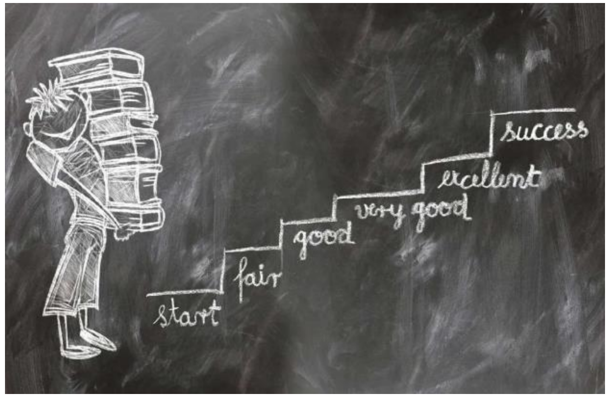
- **In Poland the disparity in scores between boys and girls is minimal and does not reach a significant level**, unlike in Italy where the difference between the two groups is very large (17.5 points) and statistically significant.
- Moreover, while the average scores of boys show little difference in the two countries, it is precisely among girls that substantial differences emerge in the scores recorded in the two national contexts.
- The analysis suggests that part of the **difference in scores between boys and girls is explained by known factors**, **which affect by decreasing the gap** between the two groups, while a significant part remains unexplained, and affects by widening the difference in scores between boys and girls. **The unexplained part is particularly large for Italy.**

MAIN FINDINGS

OAXACA BLINDER BREAKDOWN, DIFFERENCE BETWEEN MALE AND FEMALE SCORES IN MATHEMATICS, PISA 2018 DATA, ITALY-POLAND COMPARISON

	Italy	Poland
overall		
male	502.2873***	519.4854***
	[1.8748]	[1.9478]
female	484.7424***	517.0499***
	[1.7784]	[1.7329]
difference	17.5449***	2.4355
	[2.5841]	[2.6071]
explained	-12.4870***	-6.2754***
	[1.4907]	[1.4677]
unexplained	30.0319***	8.7109***
	[2.5880]	[2.4977]

Source: Inapp elaborations on PISA 2018 data



ENDOWMENTS EFFECTS

- The type of secondary school attended (tschoolt) only significantly influences the results for Italy, and it is the factor that seems to have the greatest impact. This result tends to confirm a phenomenon that is still very true for Italy, consolidated by national and international surveys in which student performance tends to vary significantly according to the type of school. And so, for example, high school students score very high, close to European countries with better results in PISA. On average, students in vocational colleges and vocational training programmes have lower results. Therefore, in our country the gap seems to be substantially associated with a characteristic of the Italian school system, which, unlike other European countries, has not yet managed to overcome the gap between technical and high school education.
- Overall, a very relevant result that should be highlighted is that, if the individual variables that affect the mathematical gap between girls and boys are substantially the same in Italy and Poland (and on these variables it would certainly be interesting to carry out in-depth analyses), the more structural scholastic characteristics, such as those reported here, affect only Italy.
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ENDOWMENTS

	Italy	Poland
explained		
Private school	0.5033***	-0.1453
	[0.1549]	[0.1839]
School type	-9.7333***	0.0681
	[0.8165]	[0.0893]
Teacher shortage	0.2312*	0.0156
	[0.1263]	[0.0419]
Lack of teaching materials	0.7242***	-0.1102
	[0.2078]	[0.1233]
Lack of infrastructure	-0.3257**	-0.0572
	[0.1641]	[0.0661]
School Internet Bandwidth	1.0121***	-0.0207
	[0.2380]	[0.0379]
Professional development	0.2167**	0.0549
	[0.1055]	[0.0610]

For Italy, **the differences** in the endowment effect are mainly attributable to problems that can be defined as "**systemic**". The shortage of teachers, the lack of teaching materials as well as the inadequacy of internet bandwidth at school, have an impact by increasing the mathematical gap between girls and boys. **These scholastic elements would seem to aggravate the role of some factors that concern individual dimensions**, such as competitiveness and orientation to the student's goal, which increase the width of the mathematical gender gap among Italian students.

The fact that students belong to a **general school (high schools) rather than a vocational school**, **seems to decrease the gap by about 10 points for Italy.** The **number of students per class also plays a significant role in the male-female gap**.

ENDOWMENTS

	Italy	Poland
Students per class (21-25)	-0.4800**	-0.0158
	[0.2360]	[0.0739]
Students per class (26-30)	-0.5537***	-0.1237
	[0.1982]	[0.1273]
Additional Italian lessons	-0.3610**	0.1907
	[0.1516]	[0.1278]
Competitiveness	1.8286***	0.7041**
	[0.4182]	[0.3363]
Goal Orientation	0.7420***	-0.7676*
	[0.2120]	[0.4473]

ENDOWMENTS

	Italy	Poland
Motivation and commitment	-1.5162***	-1.9864***
	[0.3858]	[0.3960]
Positive disciplinary climate	-1.8265***	-0.6425***
	[0.3163]	[0.2291]
Italian language spoken at home	-0.3107*	-0.1235
	[0.1674]	[0.1031]
Repeating	-3.1351***	-2.6615***
	[0.4281]	[0.5397]

Source: Inapp elaborations on PISA 2018 data

Notes - other variables included in the estimates and not significant: number of inhabitants, teachers' skills (as perceived by the Headmaster), presence of schools of the same type in the area, Italian language preparatory course, ESCS, resilience, sense of belonging, fear of failure, age, immigrant/native status.

- On the other hand, the results show that factors such as: the disciplinary climate in the classroom, commitment, having repeated the school year, play a role in decreasing the differential in the mathematical score between girls and boys in both countries analyzed. Repeating the school year could also play a positive role as the repeating student could benefit from a more favourable context, facilitated by familiarity with the material already addressed.

COEFFICIENTS

- The "**discriminating" factors in the coefficient effect affect Italy for 30 points of the gap while for Poland for just 8 points.** This result certainly indicates a greater complexity downstream of the phenomenon, which is particularly accentuated in Italy.
- From the results for Italy, it seems that **a greater school offer of the same type present in the territory to which they belong corresponds to a significant increase in the gap between girls and boys**. Increased supply appears to correlate with an increase in unexplained variation in PISA scores. We **hypothesize that in this case there may be some "school segregation effect" whereby disadvantaged groups risk going to "second-class" schools, while the best schools bring more advantaged or prepared students and the selection effect increases thanks to the duplication of the educational offer**. In line with the literature, this result is interpreted in the following way: **in schools where the top performers are concentrated, the gender gap in mathematics would tend to increase**. This is not the case for Poland.
- This reading seems to be **confirmed by the result that shows a significant decrease in the gap for those schools that have a functioning internet band at school,** which we hypothesize to be associated with a better overall efficiency of the school, and which is among the system characteristics analyzed above. These variables are significant only for Italy.
- The socio-cultural and economic level of the student has an influence for both countries, which increases the differential between groups by about 1 point for both countries.

COEFFICIENTS

	Italy	Poland
unexplained		
School type	-22.675	0.3770*
	[2.7834]	[0.2191]
Internet bandwidth at school	-5.8232*	-22.154
	[3.2427]	[2.9918]
Equal educational offer in the area	8.8216***	-52.047
	[3.2584]	[4.3918]
Students per class (16-20)	-3.0225*	0.0044
	[1.7000]	[1.1189]
Family ESCS	1.8923***	0.6644*
	[0.6005]	[0.4029]
Competitiveness	0.5001	-0.3247*
	[0.4942]	[0.1844]
Sense of belonging	0.4868***	-1.4693**
	[0.1845]	[0.6681]
Immigrate	-0.3338	0.4070*
	[0.9050]	[0.2338]

OAXACA-RIF

- The analyses carried out with the Oaxaca Rif method allowed to verify the contribution of independent variables in the various percentiles, giving greater robustness to the previous results thanks also to the observation of phenomena more concentrated along some parts of the distribution. The results of the Oaxaca Rif analysis of the mathematical gap between boys and girls in the two countries therefore contribute to a better understanding of the characteristics of this phenomenon.
- The distribution between percentiles of the gap appears to **follow a similar dynamic in both countries**. In particular, it is observed that the **mathematical gap between girls and boys tends to grow, as the distribution increases, and is highest among the most able boys (80th percentile).** Examining the distribution, it emerges that the "tangible" factors that influence the part explained, and that contribute to explaining the differential, always have a negative sign. These are therefore factors that reduce the gap in mathematics between genders and that tend to decrease as you move along the distribution.
- In the distribution **of the coefficient or "unexplained" part**, there are positive factors that widen the gap between the two groups. These factors tend to grow along the distribution. Interestingly, this dynamic, characterized by an inverse logic between explained and unexplained parts, is common to both countries.
- This econometric analysis provides a detailed perspective on the variation of the gender gap along the distribution of mathematical scores, and therefore along a continuum from the least able to the best students, capturing elements that help to better understand the complexity of this phenomenon.

DISTRIBUTION ANALYSIS

	ITALIA			POLONIA		
Percentile	20	50	80	20	50	80
overall						
Maschi	422.5562***	506.2125***	582.8960***	442.6203***	518.2137***	600.1460***
	[3.0410]	[2.5224]	[2.6770]	[2.6511]	[2.4860]	[2.7111]
Femmine	412.3605***	489.9537***	557.3648***	442.5125***	520.9479***	590.5409***
	[2.9384]	[2.2862]	[2.3979]	[2.5952]	[2.1862]	[2.5768]
difference	10.1957**	16.2588***	25.5312***	0.1079	-2.7341	9.6051**
	[4.2287]	[3.4043]	[3.5939]	[3.7099]	[3.3105]	[3.7404]
explained	-15.3128***	-12.3522***	-5.3336***	-12.1755***	-6.7847***	-7.0235***
	[2.9760]	[2.1461]	[2.0223]	[2.3487]	[1.8796]	[2.0606]
unexplained	25.5086***	28.6110***	30.8648***	12.2834***	4.0506	16.6286***
	[5.0771]	[3.6906]	[3.7711]	[4.1453]	[3.4025]	[3.7650]
explained						
Scuola privata	0.6803**	0.6694**	0.8599*	-0.1292	-0.1666	-0.151
	[0.2954]	[0.3375]	[0.4702]	[0.1681]	[0.2139]	[0.2007]
Tipologia scuola	-11.5544***	-9.1032***	-8.0238***	-0.1242	0.0713	-0.1704
	[1.9118]	[1.3647]	[1.2801]	[0.1975]	[0.1260]	[0.1348]
Carenza insegnanti	-0.1326	-0.1422	0.4613**	-0.1204	0.0254	0.0018
	[0.2837]	[0.2126]	[0.2279]	[0.1432]	[0.0713]	[0.0710]
Carenza materiale didattico	0.6395*	0.8922***	1.0214***	-0.1477	-0.1502	-0.0883
	[0.3361]	[0.2999]	[0.3100]	[0.2690]	[0.2205]	[0.2477]
Banda internet scuola	1.3954***	1.3333***	1.1123***	0.0334	0.007	-0.04
	[0.4507]	[0.3637]	[0.3457]	[0.0726]	[0.0500]	[0.0764]
Studenti per classe (26-30)	-0.7800**	-0.5706**	-0.3806*	0.0008	-0.0638	-0.1833
	[0.3676]	[0.2522]	[0.2176]	[0.0639]	[0.0863]	[0.1974]
Lezioni aggiuntive d’italiano	-0.2658	-0.4141**	-0.3214*	0.332	0.2064	-0.1757
	[0.1956]	[0.2010]	[0.1843]	[0.2347]	[0.1653]	[0.1736]

CONCLUSION

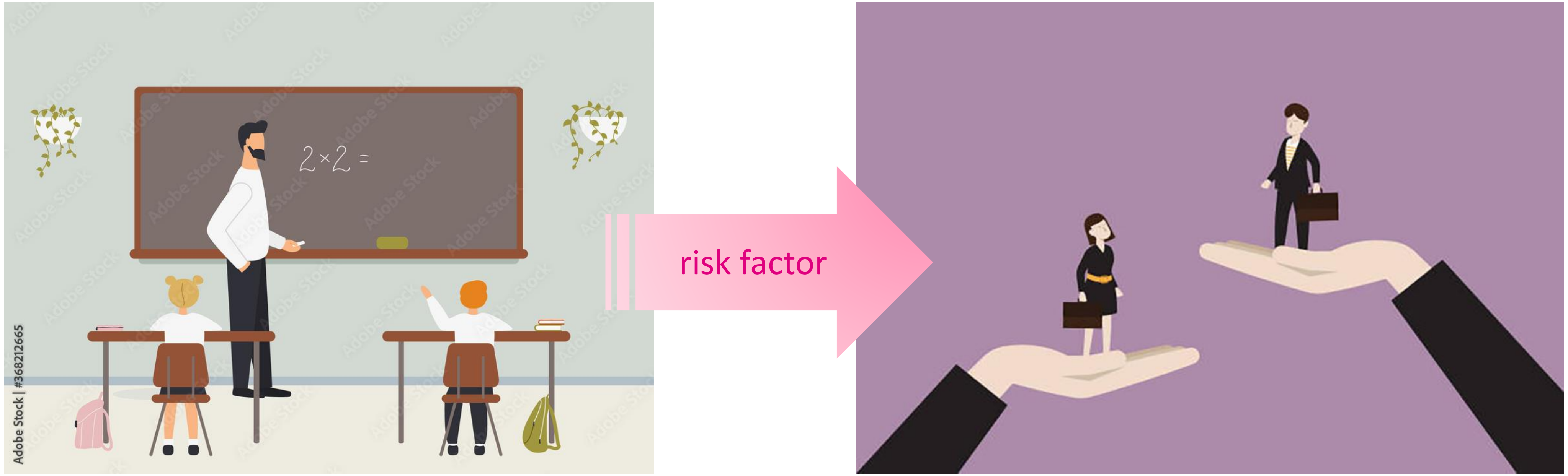
Analyzing the results of the OECD Pisa 2018 standardized tests, Italy emerges as one of the countries with the widest gender gap in mathematics learning between girls and boys.

National surveys measuring learning outcomes, such as the INVALSI tests (2023), also confirm the presence of the gender gap in mathematics at all educational levels.

The development of large-scale studies such as those by the OECD has allowed for comparisons of the gender gap across different countries, and to identify contexts where this gap is narrower and there is greater equity between girls and boys.

CONCLUSIONS

Poland is an example of a country that appears to have achieved greater equity over time. We know that greater equity also ensures university and professional training paths with less gender segregation.



- **The gender gap in Italy seems to be strongly influenced by contextual and institutional factors.** On the other hand, in **Poland, where the differential, however minimal, would seem to be more linked to individual/psychological factors between men and women** (sense of belonging, sense of failure, etc.) known to be detected by numerous studies on this phenomenon. Of course, policies cannot act at the level of individual characteristics, but they can help bring about the cultural change necessary to reduce gender stereotypes that are often internalized.
- The study confirms the role played by variables that cannot be directly observed, but above all by factors related to socio-economic contexts. This highlights a strong disparity in our country, which fails to promote equitable learning in mathematics or STEM disciplines. Considerable efforts are still needed for Italian female students to be able to get closer to the results of their male classmates in this area.
- The results of the breakdown show that putting men and women on an equal footing with respect to their personal characteristics is not enough to close the gap, and this is particularly true for Italy. In fact, in our country, among the variables that have the greatest impact on the gender gap in mathematics learning, a leading role is played by those related to the school context: type of school, number of classes but also the different attitudes of teachers towards pupils, which can influence commitment, motivation and goal orientation.

- **Stereotypes and prejudices**, even if not conscious, **can affect teachers' expectations and consequently school evaluations** (Pygmalion Effect, Rosenthal and Jacobson, 1992), and **therefore the sense of self-efficacy with respect to certain subjects or school curriculum**. This is the case of studies such as the one conducted by M.C. Murphy, C.M. Steele and J.J. Gross that examined the effect of "situational cues" on girls' performance in mathematical and scientific tasks, showing how mathematical results for women can decrease due to increased stress, reduced self-confidence or fear of confirming perceived negative stereotypes.

- **Training interventions** aimed at mathematics teachers of all levels would be necessary. These interventions should include, alongside traditional methodologies, the adoption of inclusive and innovative teaching methodologies (Baccaglini Frank et al., 2017) **that foster gender equity and promote girls' confidence and engagement in mathematics.** In addition, it is crucial to raise awareness among teachers about the self-perpetuating mechanisms of gender stereotypes and provide them with tools to mitigate their effects, in order to ensure an inclusive and developmentally conducive school environment for all students.

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