Regional differences count: An intra-national exploration of gender (in)equality in mathematics education.

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Research on gender differences in mathematics has received a lot of attention but has failed to explain important patterns across cultures and geographies. Most of the comparative research on this topic has been carried out at national level. In this paper, Italian gender gap is explored at intra-national level to understand if the national differences appear also at local (i.e. province, regional, and macro-area) levels and variations within the country are measured. A multilevel model of mathematics achievement tests administered in Italy in 2017 with grade 10 students (n=38120) confirmed the importance of the regional levels in the hierarchical data structure and revealed a strong interaction between local clustering and gender.

Intersectional; region; gender; mathematics; multilevel model; Italy

Introduction

Mathematics education faces a lot of challenges including equity issues such as gender differences and this is a timely international topic. In fact, although research on gender differences in mathematics has received increased attention in recent years, it has failed to explain important patterns across cultures and geographies. In order to understand if, how and how much social and cultural characteristics of the surrounding environment can explain differences in mathematics achievement between boys and girls, we analysed secondary data collected by the Italian National Institute for the Evaluation of Educational System (INVALSI – Istituto Nazionale per la Valutazione del Sistema di Istruzione – www.invalsi.it) in Italy from students aged 16 years old.

A multilevel regression analysis was carried out to explore the differential attainment of boys and girls in mathematics test scores. In contrast to other similar studies, we performed our analysis at intra-national level in order to understand if the (statistically significant but small) gender gap observed at national level also exists (and if so to what extent) at local (i.e. province, regional, and macro-area) levels. This decision is guided by the hypotheses that social conditioning and gender-biased environments can have very large effects on mathematics (test) performance as well as that perception of gender can vary also within the same country, at and between regional and/or provincial levels, where social conditioning may vary.

Methodology

Data and sample

To assess students' competences in mathematics INVALSI develops and administers year by year mathematics achievement tests and certifies the competence level achieved by each student. In this study, we analysed data collected from grade 10, 16 year old students (high school) in 2017 (N = 38120) drawn to be representative at national, macro-geographical and regional level (Table 1). We used sample data (instead of census) in order to control test conditions as the administration is conducted and supervised by an external INVALSI inspector to avoid cheating behaviours.

Macro-geographical area	Regions
North West	Liguria; Lombardia; Piemonte; Valle d'Aosta
North East	Emilia-Romagna; Friuli-Venezia Giulia; Bolzano; Trento; Veneto
Centre	Lazio; Marche; Toscana; Umbria
South	Abruzzo; Campania; Molise; Puglia
South and Islands	Basilicata; Calabria; Sardegna; Sicilia

Table 1. Macro-geographical areas and regions in Italy

Analytical strategy

In order to understand if and how much context (i.e., classroom, school, place of residence) affects students' performance, a multilevel analysis has been employed where the dependent variable is a (Rasch modelled *logit*) mathematics ability score. Multilevel modelling is coherent with the hierarchical structure of the Italian data (38120 individuals into 2036 classrooms, nested into 1056 schools, nested in 21 regions).

Assuming there are effects of the social context on individuals, these effects must be mediated by intervening processes that depend on characteristics of the context (Hox, 2010); multilevel modelling uses the shared variation of observations within structures levels to make estimations about mathematics ability, accounting for its nested structure.

In addition, gender differences are on average higher at the top level of the ability distribution, so, when performance is low, also gender differences tends to disappear (e.g., Hadges & Nowel, 1995; Maccoby, 1967; Pope & Sydnor, 2010; Summers, 2005). For this reason, instead of modelling differences we employed an attainment model and explored gender differences by using gender as a predictor.

Variables

Variation in mathematics ability has been explored taking into account a set of predictors at individual, classroom and school level, as detailed in the following table.

Variable	**Type of data**	**Description**
Outcome	Continuous	Mathematics test scores obtained by 10^{th}-grade pupils in 2017. Scores are estimated using the Rasch model. Mathematics test scores range approximately from 180 up to 350, with a mean of 200 and a standard deviation of 40.
Student level		
Gender	Binary	Gender of pupils, coded 1 for boys and 2 for girls
Socio-economic status (SES)	Continuous	A continuous index calculated by the Italian national institute for the evaluation of educational system. It is based on the 1) highest parental education (in number of years of education according to ISCED classification), 2) highest parental occupation, and 3) number of home possessions including books in the home, used as a proxy for family wealth because no direct income measure has been available in Italy.
Citizenship	Categorical	Citizenship has three levels, i.e. Italian, First-, and Second- generation foreign student.
Classroom level		
Socio-economic level (SES)	Continuous	A continuous index calculated as the mean of students' ESCS, per classroom
Number of students per classroom	Continuous	Number of students attending the same classroom

Variable	Type of data	Description
School level		
Socio-economic level (SES)	Continuous	A continuous index calculated as the mean of students' ESCS, per school
Number of students per school	Continuous	Number of students attending the same school
School type	Indicator variable (set of dummy variable	High school in Italy offers three different courses of studies: 1) Licei; 2) Tecnici; and, 3) Professionali. For each of them curriculum, up to grade 10, is the same but students' test scores in mathematics vary very much.

Source: Our elaboration

Table 2. Variables used to carry out the multilevel model

At school level, we have three school types (Licei, Tecnici and Professionali), with the same mathematics curriculum but very different mathematics test scores. Although each school type allows access to university and is based on the same mathematics curriculum up to grade 10, Tecnici and Professionali offer a specific education/training and a direct access to the job market in sectors that do not require an academic degree, whereas Licei offer a broader education and are preparatory to university.

Results

At national level, male performance is slightly higher than the national mean but strongly higher than female performance, i.e. around 7 points on a Rasch scale with mean 200 and standard deviation 40. These differences change when we consider a smaller geographic unit and school type (i.e., Licei, Tecnici, and Professionali): mathematics test scores tend to decrease moving from Licei to Tecnici and finally to Professionali.

Since males have higher scores than females, the reference category for 'gender' is male, so the girls' coefficient expresses how much mathematics test score varies if the respondent is a girl compared to boys' performance. The first step in the process involves the estimation of the null-model (i.e., without predictors) and the calculation of the variance partition coefficient (VPC) according to Davis & Scott's method (1995), that identifies the contribution of each level to the variation of Mathematics ability (Table 3).

		1-level model [individual level]	2-levels model [classroom level]	3-levels model [school level]	4-levels model [Region]
Fixed		Coef. (SE)	Coef. (SE)	Coef. (SE)	Coef. (SE)
Intercept		198.738(0.201)	195.632(0.633)	195.^{7173}(0.853)	196.731(2.805)
	N	VPC			
Student	38120	100%	46%	46%	45%
Classroom	2186		54%	13%	13%
School	1056			41%	31%
Region	21				10%
Total variance		100%	100%	100%	100%

Source: our elaboration of data collected by Italian National Educational System Evaluation (2017)

Table 3. Null-model and variance partition coefficient (VPC).

At each level, the intercept estimate corresponds to the sample mean for boys, whereas regression coefficients represent the effect of each predictor in terms of the variation they can explain in mathematics ability (table 4). For example, the coefficient related to gender expresses that, on average in the sample, girls score around seven points less than boys. The effect of individual students' SES is negligible when classroom and/or school level are added: the first explains around three quarter of SD that decreases to half SD when we add school level that explains a quarter of SD. This seems to suggest that the socio-economic context affects performance much more than individual students' SES. This effect (that might be caused by different factors) is true for both male and female, since the interaction effect between gender and SES is negligible both at individual and classroom level. School type explains a high proportion of variation in mathematics ability, especially for Professionali relative to Licei whereas Tecnici show an intermediate performance level. In order to explore if and how school type effect changes at geographical level and if it interacts with gender, a second order interaction effect (Girls*School_type*Region) has been added at level four. On average, gender differences are closer in north (especially in north west) and tend to increase moving from north to centre and then to south, as also confirmed by the interaction term between gender and macro-geographical area added to the highest level. On average, female disadvantage is stronger in Professionali than in Licei where students' performance is greater than in Tecnici and Professionali both at regional that at national level.

		1-level model [student]	2- level model [classroom]	3-level model [school]	4-level model [Region]
	Intercept	202.738 (0.949)	204.347(0.260)	204.959(0.260)	204.908(0.256)
	Girl	-7.777(0.421)	-10.230(0.376)	-10.732(0.374)	0.859(0.818)
	ESCS (student)	11.081(0.300)	1.016(0.224)	1.255(0.221)	1.231(0.217)
	ESCS (classroom)		39.070(0.437)	27.289(0.709)	26.712(0.711)
	ESCS (school)			16.654(0.799)	16.198(0.818)
North West	Girl * Valle d'Aosta * Liceo				-4.286(4.304)
North West	Girl * Piemonte * Liceo				-3.271(1.677)
North West	Girl * Liguria * Liceo				-12.545(1.821)
North West	Girl * Lombardia * Liceo				3.044(1.494)
North West	Girl * Valle d'Aosta * Professionale				-4.099(6.655)
North West	Girl * Piemonte * Professionale				-11.017(2.257)
North West	Girl * Liguria * Professionale				-27.742(2.409)
North West	Girl * Lombardia * Professionale				-8.955(1.892)
North East	Girl * Bolzano * Liceo				-21.897(4.962)
North East	Girl * Friuli Venezia Giulia * Liceo				-9.231(1.796)
North East	Girl * Emilia Romagna * Liceo				-10.251(2.075)
North East	Girl * Bolzano * Professionali				2.040(13.921)
North East	Girl * Friuli Venezia Giulia * Professionale				-17.987(3.142)
North East	Girl * Emilia Romagna * Professionale				-14.539(2.507)
Centre	Girl * Toscana * Liceo				-5.251(1.660)
Centre	Girl * Umbria * Liceo				-9.834(2.088)
Centre	Girl * Marche * Liceo				5.886(2.661)
Centre	Girl * Lazio * Liceo				-16.335(1.861)

		1-level model [student]	2- level model [classroom]	3-level model [school]	4-level model [Region]
	Girl * Toscana * Professionali				-11.839(2.658)
	Girl * Umbria * Professionale				-11.743(3.931)
	Girl * Marche * Professionale				-4.670(2.516)
	Girl * Lazio * Professionale				-19.811(2.473)
South	Girl * Abruzzo * Liceo				-2.792(3.145)
	Girl * Molise * Liceo				1.150(2.221)
	Girl * Campania * Liceo				1.945(1.462)
	Girl * Puglia * Liceo				4.109(1.746)
	Girl * Abruzzo * Professionale				-2.239(3.462)
	Girl * Molise * Professionale				-13.354(4.700)
	Girl * Campania * Professionale				4.481(2.065)
	Girl * Puglia * Professionale				4.103(2.380)
South and Islands	Girl * Basilicata * Liceo				8.429(2.300)
	Girl * Calabria * Liceo				-3.069(2.521)
	Girl * Sicilia * Liceo				-9.748(2.264)
	Girl * Sardegna * Liceo				-7.682(13.893)
	Girl * Basilicata * Professionale				-1.250(3.781)
	Girl * Calabria * Professionale				-7.690(3.128)
	Girl * Sicilia * Professionale				1.361(2.531)
	Girl * Sardegna * Professionale				-10.687(3.159)
	Girl * North West				-1.803(1.461)
	Girl * Centre				-9.127(1.547)
	Girl * South				-13.460(1.523)
	Girl * South and Islands				-20.498(1.667)

Source: our elaboration on INVALSI SNV data (2017)

Table 4. Multilevel analysis to quantify gender differences in mathematics, at regional level

Conclusions

At national level, male advantage is statistically significant but so small as to be negligible. Nevertheless, moving from the national to the regional level of analysis, gender disparities in mathematics ability significantly vary depending on locality (with bigger gender differences in south relative to north with some few exceptions) as well as on school type. Empirical findings confirmed the hypothesis that the gap in test scores between boys and girls observed at national level is not visible to the same extent throughout the country, and that variations are geographically clustered. In particular, the multilevel analysis shows differences between boys and girls both within and between macro-geographical areas, i.e. between regions, suggesting that the gender differences do need to be explained by taking into account local rather than national explanations.

This conclusion raises a question: how and why do smaller geographical areas differ from the national average, i.e. which factors change and how do they affect students' performance? Ongoing analyses are aimed to answer this question.

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