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Is the math gender gap associated with gender equality? Only in low-income countries

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ABSTRACT

In their seminal article, Guiso *et al.* (2008) uncover a positive relationship between several measures of gender equality and the math gender gap (which tends to favor boys) by exploiting cross-sectional variation in PISA test scores from 39 countries - the majority of which belong to the OECD - at a given year (2003). Using five waves of PISA data spanning the period 2003-2015 and exploiting variation both across- and within-countries, we find that the positive association between the female-male gender gap in math test scores and several measures of gender equality vanishes in OECD countries once we account for country fixed effects. Interestingly, our analysis also uncovers a positive and statistically significant association between the math gender gap and several gender equality indicators for countries in the bottom quartile of per capita GDP. This association is robust to controlling for country-level time-invariant unobserved heterogeneity.

1. Introduction

Understanding whether more gender equal societies narrow the gender gap in math, which tends to favor boys,[1] is a highly policy relevant question that many researchers have investigated.[2] Investigating the roots of the math gender gap is relevant for the promotion of gender equality in light of the well documented underrepresentation of women in math and science in higher education (Turner and Bowen, 1999) and in math-related occupations (Paglin and Rufolo, 1990), which is in turn associated with lower wages (Machin and Puhani, 2003; Black *et al.*, 2008).

In their seminal article, Guiso *et al.* (2008) uncover a positive relationship between several measures of gender equality and the math gender gap between high-school girls and boys.[3] Exploiting cross-sectional variation in the Program for International Student Assessment (hereafter PISA) test scores from 39 countries - the majority of which belong to the OECD - at a given year (2003), the authors find that girls' performance in math tests is closer to that of boys (or even better) in those countries where social and economic conditions are relatively more favorable to women.

We revisit and expand their findings by taking advantage of the current availability of more waves of PISA data spanning the period

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[1] See for instance Guiso *et al.* (2008), Fryer and Levitt (2010), Bedard and Cho (2010), Ellison and Swanson (2010), Pope and Sydnor (2010), Nollenberger, Rodríguez-Planas and Sevilla (2016), Rodríguez-Planas and Nollenberger (2018).

[2] Gevrek *et al.* (2020) apply a semiparametric Oaxaca-Blinder decomposition to PISA data, and they find that the part of the female-male gap in math test scores that cannot be explained by gender differences in observable characteristics is indeed related to several gender equality indicators. This is clearly consistent with the findings obtained by Guiso *et al.* (2008) using regression analysis. A complementary strand of the literature has instead focused on the relationship between non gender-related inequalities and the math gender gap. See, for instance, Breda, Jouini, and Napp (2018) and the references therein.

[3] One would expect the female-male math gender gap (or the male-female math gender gap) to be larger (smaller) in more gender equal countries. In other words, girls' relative disadvantage in math performance is expected to attenuate in more gender equal countries. This is because gender differences in status and gender segregation, for example with respect job opportunities, may affect numerous socialization processes that shape gender differences in students' motivation, beliefs and attitudes towards mathematics, potentially affecting teachers and parents too. This idea is known as the gender stratification hypothesis (Baker and Jones, 1993).

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Table 1
Descriptive statistics of average gender gap and average indices of gender equality

	PISA sample of students above the median of the ESCS of each country		PISA sample of all students	
	OECD countries	Non-OECD countries	OECD countries	Non-OECD countries
Panel A				
Average gender gap				
Math	-9.883	-3.665	-10.202	-4.678
	(7,380)	(10,331)	(6,923)	(10,322)
Reading	35.353	38.873	35.697	37.695
	(9,947)	(13,652)	(10,302)	(14,741)
Average PISA score of boys				
Math	520.475	440.212	490.885	417.972
	(7,996)	(9,673)	(5,318)	(9,176)
Reading	503.566	426.738	473.851	403.920
	(4,914)	(10,079)	(5,006)	(11,045)
Average PISA score of girls				
Math	509.061	434.051	479.284	409.065
	(5,766)	(11,974)	(4,115)	(10,611)
Reading	533.923	459.251	504.508	434.467
	(5,449)	(10,698)	(5,037)	(9,414)
Panel B				
Indices of gender equality				
GGI	0.722	0.677	0.722	0.677
	(0,056)	(0,035)	(0,056)	(0,034)
Economic opportunity index	0.673	0.632	0.673	0.632
	(0,093)	(0,099)	(0,093)	(0,098)
Political empowerment index	0.249	0.125	0.249	0.126
	(0,153)	(0,070)	(0,153)	(0,070)
Educ. attainment index	0.992	0.983	0.992	0.983
	(0,018)	(0,019)	(0,018)	(0,019)
Health and survival index	0.976	0.969	0.976	0.969
	(0,004)	(0,014)	(0,004)	(0,015)
Ratio FLFP/MLFP (%)	76.648	68.956	76.648	68.856
	(10,665)	(15,916)	(10,665)	(15,802)

Notes: Standard deviation in parenthesis. Average PISA score is calculated as the average of PISA years 2003-2015.

2003-2015. This allows us to exploit variation both across- and within-countries in order to shed further light on the association between gender equality and the math gender gap. In particular, we investigate whether this association is still relevant once unobserved time invariant heterogeneity is accounted for, and we analyze whether it is heterogeneous across different levels of development.

Our paper also speaks to a related literature that focuses on the role played by gender social norms or cultural attitudes towards gender. Studies focusing on the impact of culture have often relied on the epidemiological approach. This approach aims at isolating the effects of culture (both its permanent and its non-permanent components) from the effects of formal institutional factors on different outcomes by comparing second-generation immigrants born in a given country (as they share the same formal institutions) with different ancestries.[4] In the context of the math gender gap, Nollenberger, Rodríguez-Planas and Sevilla (2016) find that greater gender equality in second-generation immigrants' countries of ancestry decreases the math gender gap in their host countries (where they were born and live), while Rodríguez-Planas and Nollenberger (2018) show that this finding expands to other subjects.

While our paper is related to this literature, our goal is *not* to isolate the effects of gender social norms or culture/informal institutions involving gender. The gender equality indicators used in Guiso *et al.* (2008) and in this paper are likely the combined result of several policy, socioeconomic, and cultural variables. Hence, they should not be interpreted as reflecting culture alone. Instead, we focus on the relationship between gender inequalities and the math gender gap. We investigate whether this association is still relevant once country-specific time-invariant heterogeneity –which may well include, for instance, the permanent component of culture– is accounted for, and we study whether it varies across different levels of economic development.

We find that, once we control for time-invariant unobserved country heterogeneity, the positive and significant association between different indicators of gender equality and the relative performance of girls in mathematics vanishes in both Guiso *et al.* (2008) original sample (which consisted mostly of OECD countries), and in the sample of OECD countries surveyed by PISA during the period 2003-2015. Additionally, we show the association between gender equality and the math gender gap varies depending on countries' level of economic development. In particular, we uncover a positive and significant association between the math gender gap and several gender equality indicators in countries in the bottom quartile of the GDP per capita distribution.

The remainder of the paper is organized as follows. Section 2 introduces the data, Section 3 discusses our empirical approach, Section 4 presents the results, and Section 5 discusses some robustness checks. Conclusions follow.

2. Data

2.1. PISA Data

Every three years, the Organization for Economic Cooperation and Development (OECD) conducts the PISA, an internationally standardized assessment administered to 15-year olds in schools. PISA's objective is to determine whether students have acquired the human capital needed to function in society near the end of compulsory education. In the case of mathematics, PISA's literacy "*is an individual's capacity to formulate, employ and interpret mathematics in a variety of contexts. It includes reasoning mathematically and using mathematical concepts, procedures, facts and tools to describe, explain and predict phenomena. It assists individuals to recognize the role that mathematics plays in the world and to make the well-founded judgments and decisions needed by constructive, engaged and reflective citizens*" (OECD 2017b).

While PISA only collected data for 39 countries in 2003, by 2015 73 countries spanning all continents had conducted the PISA assessment (Appendix Table A1). Note that our benchmark analyses will be based on students in the upper half of each country socioeconomic status distribution as in Guiso *et al.* (2008).[5] The reason for this is to avoid attrition bias due to potential differential drop-out rates between genders in different countries. Our results, however, are robust to including all students in the estimations, as we will later show.

[4] Previous studies relying on this approach have looked into the effects of the source-country gender gaps in wages (Antecol, 2001), labor force participation (Antecol, 2000), and smoking (Rodríguez-Planas and Sanz-de-Galdeano, 2019) on the same gaps for immigrants living in the same host country.

[5] The PISA dataset collects an indicator called Economic, Social and Cultural Status (ESCS) that measures students' socio-economic status using both parental education, parental occupation, and home possessions. In each country, we computed the 50th percentile of ESCS (taking into account the students' final weights) and dropped all the observations below that threshold for our benchmark analyses.

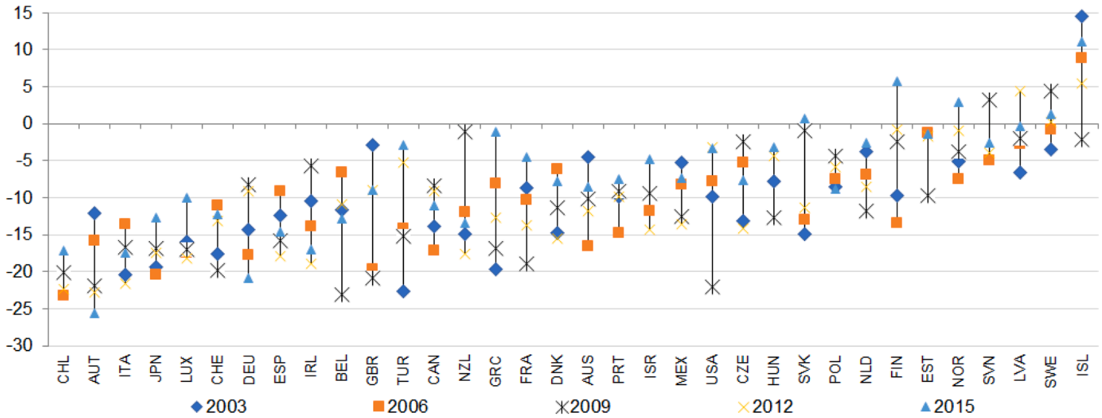

Figure 1. Gender gap in Math. OECD countries
Note: Countries are ranked according to the average gender gap in Math over the period 2003-2015, from the more negative gender gap to more positive gender gap. PISA sample of students above the median of the ESCS of each country.

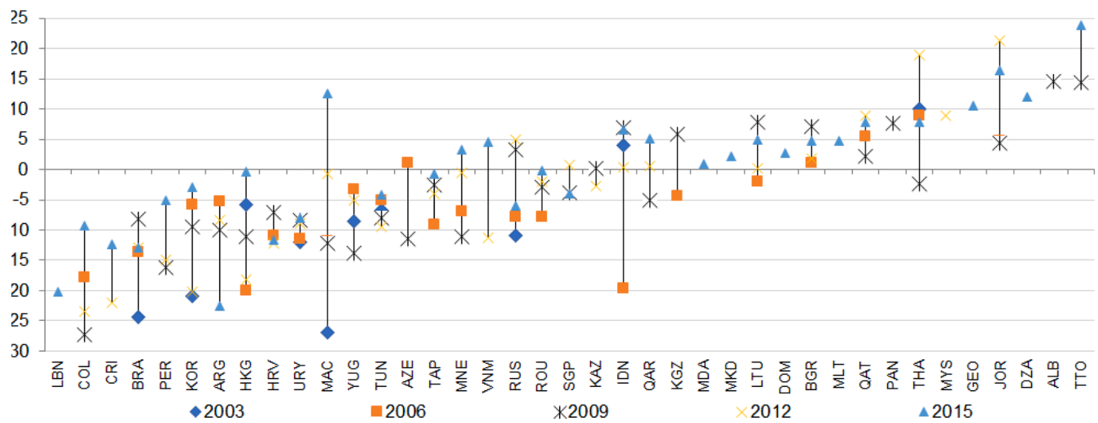

Figure 2. Gender gap in Math. Non-OECD countries
Note: Countries are ranked according to the average gender gap in Math over the period 2003-2015, from the more negative gender gap to more positive gender gap. PISA sample of students above the median of the ESCS of each country.

According to PISA data, over the 2003-2015 period, non-OECD male and female students underperform their OECD counterparts in math by a similar amount: 80 points for males and 78.5 points for females. As for the average gender gap, girls underperform boys in math test scores by 9.9 score points in OECD countries and 3.7 score points in non-OECD countries (see Table 1).[6,7]

The math gender gap markedly varies both across OECD and non-OECD countries as shown in Appendix Table A1, and in Figures 1 and 2, becoming negligible in some countries (such as Sweden or Indonesia) while being reversed in others (such as, for instance, Iceland and Malaysia in several years).

Equally important for our purposes is the fact that the math gender gap is far from constant, that is, it also varies over time within countries, as visual inspection of Figures 1 and 2 also reveals. In addition, Table 2 below shows that within country variation accounts for about 61.5% and 54.9% of the total observed variation in the math gender gap in our pooled sample of OECD and non-OECD countries, respectively.

2.2. *Country-level gender equality measures*

Using country and year identifiers, we merge PISA data from these 73 countries with time-varying gender equality measures, obtaining a sample of 166 country/year data points for 34 OECD countries and 115 country/year data points for 38 non-OECD countries. In line with Guiso *et al.* (2008), we use several alternative and complementary measures of gender equality. In particular, we use the global Gender Gap Index (GGI hereafter), its four subindexes, and the female/male labor force participation ratio (FMLFP).

Both the GGI and the FMLFP ratio are available for virtually each

[6] Because PISA offers five alternative estimates (known as plausible values) of students' ability in each subject, the procedure used to estimate test scores involves calculating the required statistic five times, one for each plausible value (see the OECD recommendations in OECD (2017a). Hence, we calculated the math gender gap in test scores in each country by running a linear regression of each of the plausible values on a constant and a female dummy variable. We then took the average of the five estimated coefficients on the gender dummy in the five regressions as the final gender gap for each particular country.

[7] Note that when we use the sample of all students, the total number of observations increases by two. In this sample there is one country (Albania) which has two more observations - for the years 2012 and 2015 - with respect to the case when we use only the sample of students who are above the median of the ESCS. For this country, the ESCS is not available for these two years (2012 and 2015), therefore we cannot include them in the estimations.

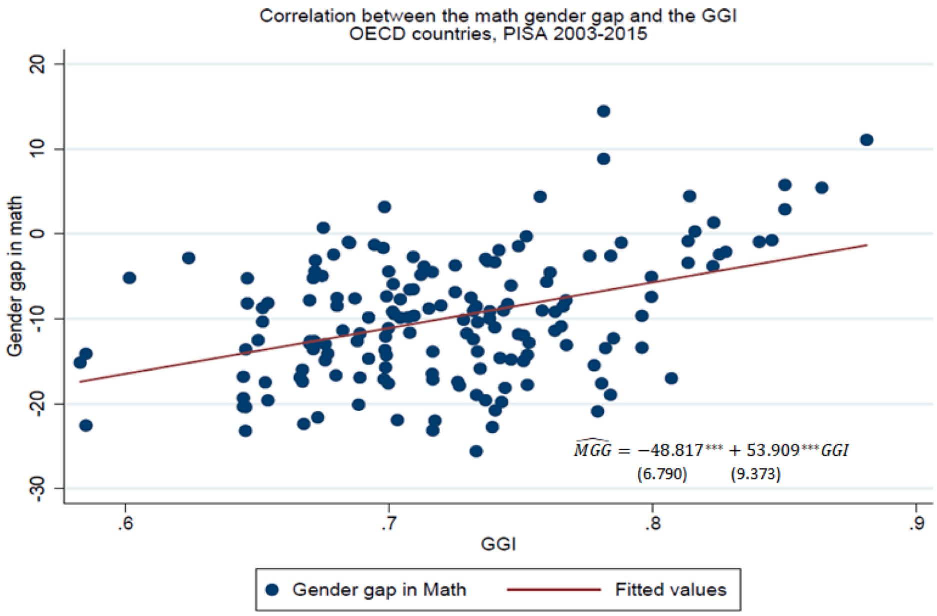

Figure A1. Correlation between in the math gender gap and the GGI OECD countries, PISA 2003-2015
Notes:
*** p<0.01, ** p<0.05, * p<0.1
PISA sample of students above the median of the ESCS of each country.

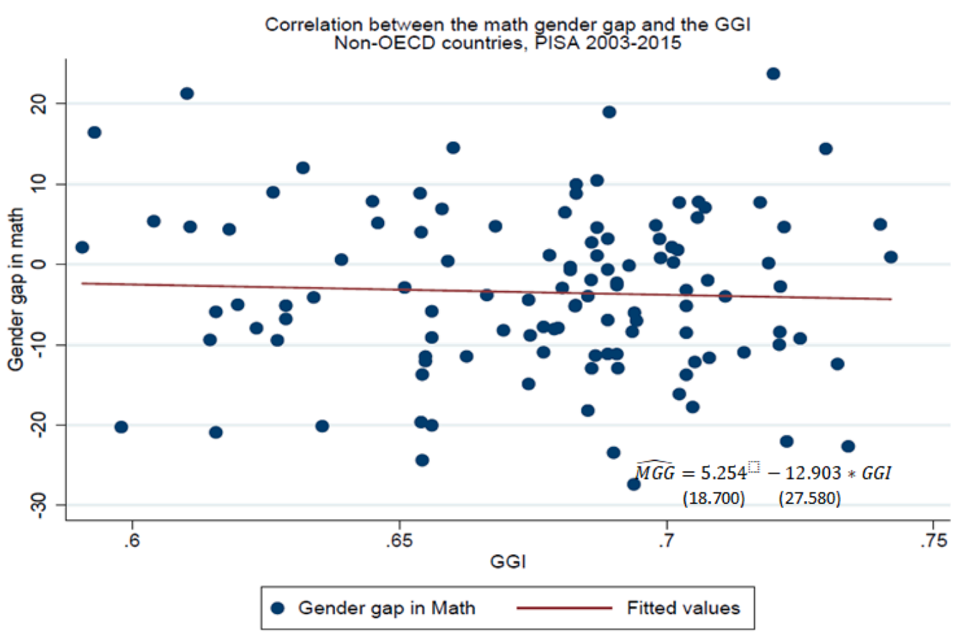

Figure A2. Correlation between in the math gender gap and the GGI Non-OECD countries, PISA 2003-2015
Notes:
*** p<0.01, ** p<0.05, * p<0.1
PISA sample of students above the median of the ESCS of each country.

country and year for which we have PISA data. [8]

The GGI is an index calculated by the World Economic Forum that measures the gap between men and women in four fundamental areas: economic participation and opportunity, political empowerment, educational attainment, and health and survival (World Economic Forum, 2018). These dimensions are the four subindexes which form the global GGI. The global GGI aims at capturing the magnitude of gender-based disparities and tracking their progress over time. For all four subindexes, as well as for the global GGI (which is computed as a simple average of each subindex score), the highest possible score is 1 (gender parity) and the lowest possible score is 0 (imparity). The methodology used to compute the GGI, based on data compiled and/or collected by the World Economic Forum, has remained stable over time, providing a basis for robust comparisons across countries and over time.

The Economic Participation and Opportunity subindex captures three concepts: the labor force participation gap, the remuneration gap and the advancement gap (the latter being measured through the ratio of women to men among legislators, senior officials and managers, and the ratio of women to men among technical and professional workers).

The Political Empowerment subindex measures the gap between men and women at the highest level of political decision-making through the ratio of women to men in ministerial positions, the ratio of women to men in parliamentary positions, and the ratio of women to

[8] When using the FMLFP ratio, we lose one country (Macedonia) and when using the GGI, we lose another country (Macao-China). See Appendix Table A1 for more details.

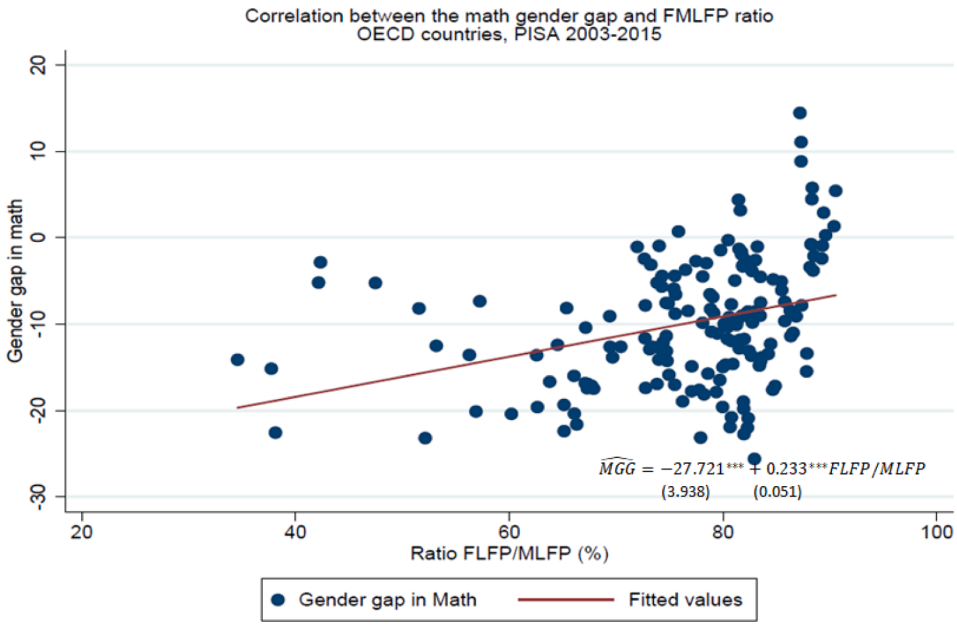

Figure A3. Correlation between in the math gender gap and FMLFP ratio OECD countries, PISA 2003-2015
Notes:
*** $p<0.01$, ** $p<0.05$, * $p<0.1$
PISA sample of students above the median of the ESCS of each country.

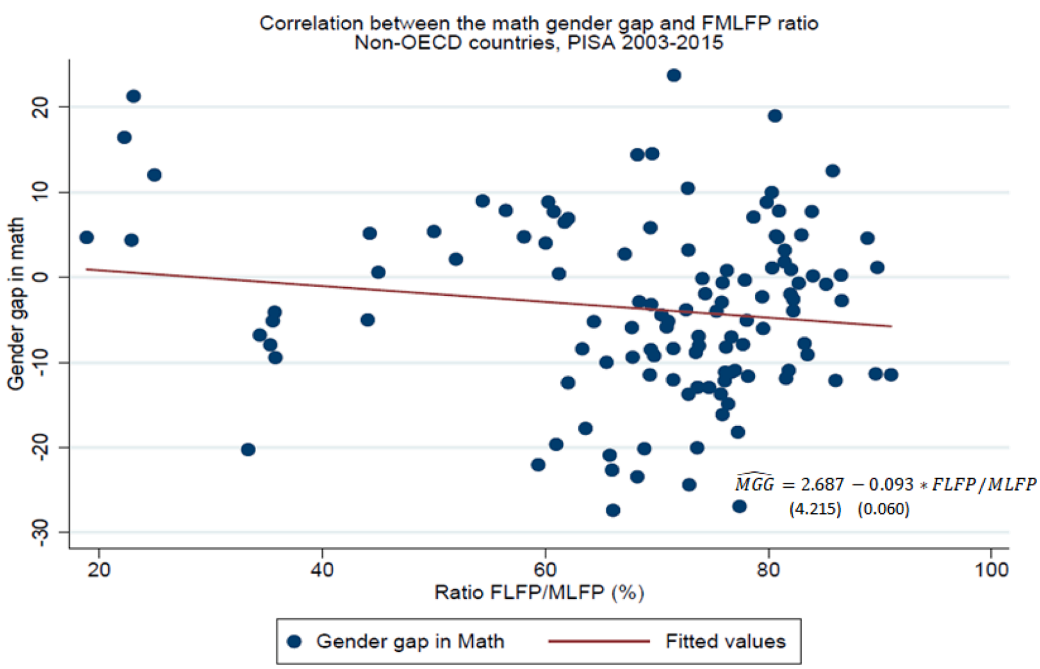

Figure A4. Correlation between in the math gender gap and FMLFP ratio Non-OECD countries, PISA 2003-2015
Notes:
*** $p<0.01$, ** $p<0.05$, * $p<0.1$
PISA sample of students above the median of the ESCS of each country.

men in terms of years in executive office for the last 50 years.

The Educational Attainment subindex captures the gap between women's and men's current access to education through ratios of women to men in primary-, secondary- and tertiary-level education, and through the female to male ratio in literacy rates.

The Health and Survival subindex captures differences between women's and men's health through the sex ratio at birth and the gender gap in life expectancy. [9]

As stressed by the World Economic Forum (2018) the GGI measures *gaps* in outcomes "in access to resources and opportunities in countries, rather than the actual levels of the available resources and opportunities in those countries". Hence, the GGI ranks countries according to gender equality rather than women's empowerment in order to decouple it from countries' levels of development.

Moreover, we use the ratio of female to male labor force participation ratio (FMLFP ratio, expressed as a percentage) as an additional and complementary measure of gender equality. The FMLFP ratio is constructed using data from the World Bank's World Development Indicators, and it measures the proportion of the individuals aged 15 and older who are available for producing goods and services in the market economy.[10]

[9] For further details on the construction process of the global GGI and its four subindexes as well as the indicators they rely on see World Economic Forum (2018).

[10] Unpaid workers, family workers, and students are often omitted, and some countries do not count members of the armed forces.

Table 2
Percentage of the total variation in the math and reading gender gaps, and in different gender equality indicators attributable to within country-across time variation.

	OECD countries		Non-OECD countries		All countries	
	%	No. of obs. (countries and years)	%	No. of obs. (countries and years)	%	No. of obs. (countries and years)
Average Math gender gap	61.46%	166	54.86%	125	54.71%	291
Average Reading gender gap	62.81%	165	51.63%	125	56.03%	290
GGI	37.85%	166	33.28%	115	33.58%	281
Econ. index	43.87%	166	30.40%	115	37.73%	281
PEI	35.48%	166	36.61%	115	32.07%	281
Educ. index	49.83%	166	44.67%	115	46.51%	281
Health index	24.92%	166	47.70%	115	23.41%	281
FMLFP ratio	24.10%	166	9.04%	119	15.90%	285

Importantly, all the country-level indicators we consider reflect gender gaps in outcomes related to health, education, economic participation and political empowerment, rather than inputs (World Economic Forum, 2018). These outcomes are in turn the result of different inputs such as, for instance, culture, customs, or legislations. In other words, our gender equality indicators are likely the combined result of several policy, socioeconomic, and cultural variables. Hence, they should not be interpreted as reflecting neither culture alone nor the persistent component of cultural attitudes towards gender.[11] As expected, our main gender equality indicators (the GGI and the FMLFP ratio) are positively and significantly correlated with each other both in OECD (0.7655, p-value=0.00) and in non-OECD countries (0.6727, p-value=0.00).

On average, there is greater gender equality in OECD than non-OECD countries (see Table 1), as the averages of both the GGI and the FMLFP ratio are higher in OECD than in non-OECD countries (0.72 versus 0.68 for the GGI and 76.6% versus 69% for the FMLFP ratio). In line with this evidence, the correlations between these gender equality indicators and the GDP per capita in the full sample of countries are relatively large, positive and significant: 0.2508 (p-value=0.00) for the GGI, and 0.1871 (p-value=0.0015) for the FMLFP ratio.

One may expect cultural values involving gender or gender social norms to be quite stable over time, or, at least, to change more slowly than, for instance, economic, political, and educational indicators of gender equality. However, as discussed above, the GGI, its components, and the FMLFP likely reflect both cultural and non-cultural factors linked to gender equality. Hence, it is expected that their within country variability is not negligible. This indeed is shown in Table 2, where we have computed the percentage of the variation in all our gender equality indicators that can be attributed to within country-across time variation. To obtain these percentages we first compute the raw standard deviation of all our gender equality indicators in our pooled samples. Next, we regress those indicators on country fixed effects and obtain the residuals. Then we compute the standard deviation of those residuals (which reflect our gender equality indicators clean of country fixed effects or within country variation). Finally, we divide it by the raw standard deviation calculated initially.

Such temporal variation can be exploited —on top of the cross-country variation illustrated in Appendix Table A1 and Figures 1 and 2 that has been used exploited by Guiso *et al.* (2008)— in order to estimate the effect of gender equality on the math gender gap while holding constant time-invariant unobserved factors.

3. Results

3.1. Replicating Guiso et al. (2008) Using 5 Waves of PISA Data

As a benchmark for later comparisons, we begin replicating earlier findings from Guiso *et al.* (2008) by applying their statistical model to pooled data from five PISA waves spanning the 2003-2015 period. We regress the math gender gap for country *i* at time *t* (Y_{it}) on the country's gender equality indicator GE_{it} (we will use the global GGI, its four subindexes and FMLFP) and the logarithm of its Gross Domestic Product ($\log GDP_{it}$) per capita in PPP as shown in equation (1) below:

$$Y_{it} = \alpha_1 + \alpha_2 GE_{it} + \alpha_3 \log GDP_{it} + \varepsilon_{it} \tag{1}$$

Note that the estimated association between the math gender gap and the gender equality indicator in equation (1) is based on the cross-country variation in this indicator—while holding constant the level of economic development, proxied by the log of the GDP per capita.

In Panel A in Table 3, we use the same countries as in Guiso *et al.* (2008), but expand the analysis to the additional four waves of PISA data currently available.[12] Each column uses an alternative measure of gender equality: the overall GGI, its four subindexes, and the FMLFP ratio. Panels B and C expand the analysis to additional countries available in PISA in waves two to five, with Panel B showing results for OECD countries, and Panel C showing results for non-OECD countries.

Consistent with Guiso *et al.* (2008), we generally observe a positive and statistically significant association between the female-male gender gap in math test scores and our different measures of gender equality in Panel A. These results indicate that Guiso *et al.* (2008) findings for 2003 still hold when including four additional waves of data. Note that their estimated effect of GGI falls within our 95% confidence interval.

Results from Panel B indicate that, in OECD countries with greater gender equality, girls perform better in math relative to boys than in OECD countries with lower gender equality. As most (75%) of Guiso *et al.*'s sample consisted of OECD countries, this result corroborates their findings.

In contrast, Panel C in Table 3 reveals that the association between either measure of gender equality and the math gender gap in non-OECD countries is sometimes negative (albeit much smaller in absolute value than in OECD countries) and always far from statistically significant at standard levels of testing. This suggests that earlier findings appear to be sensitive to the level of economic development achieved in the countries under study. The results we obtain are very similar when we use the full

[11] Note that values and beliefs may also evolve in response to or in conjunction with changes in economic, social, or political conditions (see Inglehart and Welzel, 2005, Algan and Cahuc, 2010, Ananyev and Guriev, 2018, Giavazzi et al., 2019, and Zanella and Bellani, 2019, as well as the references therein).

[12] Needless to say, when we estimate model (1) using data for year 2003 only, as Guiso *et al.* (2008) do, we are also able to replicate their findings.

Table 3
Gender gap in PISA math test and gender equality measures. PISA sample of students above the median of ESCS of each country

Pooled cross-sectional analysis						
Panel A. Guiso et al. (2008) sample	(1)	(2)	(3)	(4)	(5)	(6)
GGI	76.785***					
	(15.412)					
Econ. index		41.328***				
		(8.751)				
PEI			20.928***			
			(6.447)			
Educ. index				75.489***		
				(16.539)		
Health index					-42.328	
					(69.946)	
FMLFP ratio						0.260***
						(0.093)
Log of GDP pc in PPP	-7.930***	-6.863***	-6.371***	-4.619**	-3.599**	-5.720***
	(1.750)	(1.591)	(1.576)	(1.884)	(1.755)	(2.072)
Constant	17.656	33.937**	51.726***	-36.318**	69.137	30.377
	(15.196)	(14.691)	(16.308)	(17.668)	(65.817)	(18.337)
R-squared	0.266	0.244	0.184	0.086	0.060	0.133
	184	184	184	184	184	199
No. of countries	37	37	37	37	37	40
Panel B. OECD countries						
GGI	78.920***					
	(15.189)					
Econ. index		43.429***				
		(8.815)				
PEI			22.205***			
			(6.178)			
Educ. index				66.288***		
				(19.370)		
Health index					-340.454	
					(351.679)	
FMLFP ratio						0.343***
						(0.106)
Log of GDP pc in PPP	-7.056***	-6.281***	-4.840**	-2.173	-1.982	-5.973***
	(1.790)	(1.360)	(1.966)	(2.369)	(2.529)	(1.594)
Constant	6.759	26.448*	35.107*	-52.950**	343.058	26.161
	(16.439)	(14.021)	(20.193)	(23.826)	(352.359)	(15.955)
R-squared	0.266	0.230	0.177	0.027	0.030	0.184
Observations	166	166	166	166	166	166
No. of countries	34	34	34	34	34	34
Panel C. Non-OECD countries						
GGI	-10.435					
	(51.838)					
Econ. index		4.277				
		(17.665)				
PEI			-23.885			
			(20.399)			
Educ. index				54.539		
				(52.962)		
Health index					14.719	
					(80.448)	
FMLFP ratio						-0.095
						(0.095)
Log of GDP pc in PPP	0.866	0.978	0.655	0.952	0.996	0.720
	(1.832)	(1.891)	(1.667)	(1.728)	(1.710)	(1.379)
Constant	-4.842	-15.704	-6.868	-66.371	-27.440	-4.205
	(44.584)	(24.521)	(17.585)	(51.476)	(76.713)	(15.862)
R-squared	0.006	0.006	0.031	0.015	0.005	0.023
Observations	115	115	115	115	115	119
No. of countries	38	38	38	38	38	38

Notes: Standard errors clustered at country level in parentheses
*** $p<0.01$,
** $p<0.05$,
* $p<0.1$.

Table 4
Gender gap in PISA math test and gender equality measures. PISA sample of students above the median of ESCS of each country

Pooled cross-sectional analysis with year fixed effects						
Panel A. Guiso et al. (2008) sample	(1)	(2)	(3)	(4)	(5)	(6)
GGI	73.717***					
	(17.079)					
Econ. index		39.442***				
		(9.521)				
PEI			19.875***			
			(6.810)			
Educ. index				64.309***		
				(18.272)		
Health index					-39.680	
					(70.692)	
FMLFP ratio						0.251***
						(0.091)
Log of GDP pc in PPP	-7.942***	-6.874***	-6.507***	-4.766**	-3.939**	-5.999***
	(1.759)	(1.604)	(1.585)	(1.884)	(1.771)	(2.058)
Constant	19.299	34.764**	52.265***	-24.909	68.696	32.382*
	(15.526)	(14.852)	(16.470)	(19.921)	(66.044)	(18.341)
R-squared	0.280	0.256	0.210	0.119	0.101	0.180
	184	184	184	184	184	199
No. of countries	37	37	37	37	37	40
Panel B. OECD countries						
GGI	78.982***					
	(17.678)					
Econ. index		44.378***				
		(10.715)				
PEI			21.432***			
			(6.666)			
Educ. index				58.565***		
				(19.472)		
Health index					-334.203	
					(354.687)	
FMLFP ratio						0.338***
						(0.111)
Log of GDP pc in PPP	-7.163***	-6.457***	-4.927**	-2.326	-2.273	-6.129***
	(1.882)	(1.419)	(2.025)	(2.412)	(2.529)	(1.633)
Constant	7.904	28.053*	35.682*	-44.304*	339.181	27.992*
	(16.597)	(14.027)	(20.592)	(24.151)	(355.112)	(16.175)
R-squared	0.281	0.248	0.196	0.057	0.065	0.123
Observations	166	166	166	166	166	166
No. of countries	34	34	34	34	34	34
Panel C. Non-OECD countries						
GGI	-29.581					
	(53.173)					
Econ. index		1.943				
		(17.549)				
PEI			-37.433*			
			(20.006)			
Educ. index				37.450		
				(50.955)		
Health index					7.029	
					(77.900)	
FMLFP ratio						-0.087
						(0.094)
Log of GDP pc in PPP	0.191	0.477	-0.174	0.498	0.482	0.250
	(1.895)	(2.000)	(1.694)	(1.858)	(1.835)	(1.445)
Constant	9.309	-14.061	-3.514	-49.455	-19.746	-6.673
	(45.557)	(24.851)	(17.986)	(52.355)	(73.338)	(16.439)
R-squared	0.074	0.065	0.124	0.069	0.065	0.104
Observations	115	115	115	115	115	119
No. of countries	38	38	38	38	38	38

Notes: Standard errors clustered at country level in parentheses
*** p<0.01,
** p<0.05,
* p<0.1.

Table 5
Gender gap in PISA math test and gender equality measures. PISA sample of students above the median of ESCS of each country

Panel analysis (with year and country fixed effects)						
Panel A. Guiso et al. (2008) sample	(1)	(2)	(3)	(4)	(5)	(6)
GGI	-5.103					
	(29.114)					
Econ. index		-15.249				
		(16.541)				
PEI			1.355			
			(10.190)			
Educ. index				76.009*		
				(42.621)		
Health index					-111.527	
					(177.352)	
FMLFP ratio						-0.185
						(0.280)
Log of GDP pc in PPP	10.176	8.118	10.377	6.990	10.767	16.270*
	(7.116)	(7.336)	(6.896)	(6.801)	(6.874)	(8.839)
Constant	-109.859	-82.816	-115.725	-155.883**	-10.703	-162.898
	(82.041)	(80.190)	(70.395)	(62.956)	(194.732)	(104.362)
R-squared	0.099	0.104	0.099	0.113	0.101	0.168
	184	184	184	184	184	199
No. of countries	37	37	37	37	37	40
Panel B. OECD countries						
GGI	-15.873					
	(26.018)					
Econ. index		-14.123				
		(17.083)				
PEI			-3.204			
			(8.490)			
Educ. index				59.455		
				(42.600)		
Health index					-52.777	
					(278.434)	
FMLFP ratio						-0.404*
						(0.206)
Log of GDP pc in PPP	8.401	7.000	8.701	5.867	9.077	5.460
	(9.318)	(9.439)	(9.238)	(8.631)	(9.194)	(10.126)
Constant	-86.311	-74.011	-99.902	-129.983	-52.965	-37.259
	(103.455)	(102.403)	(95.855)	(88.054)	(289.703)	(111.930)
R-squared	0.104	0.107	0.103	0.113	0.102	0.123
Observations	166	166	166	166	166	166
No. of countries	34	34	34	34	34	34
Panel C. Non-OECD countries						
GGI	18.970					
	(60.565)					
Econ. index		2.212				
		(15.587)				
PEI			6.821			
			(30.143)			
Educ. index				7.680		
				(67.597)		
Health index					-35.444	
					(128.428)	
FMLFP ratio						0.348
						(0.420)
Log of GDP pc in PPP	0.379	0.783	0.407	0.603	0.597	12.085
	(9.356)	(9.074)	(9.413)	(9.444)	(9.297)	(10.252)
Constant	-22.452	-15.026	-10.787	-19.457	22.411	-146.554
	(86.998)	(85.658)	(87.859)	(89.490)	(192.658)	(110.605)
R-squared	0.140	0.140	0.140	0.140	0.140	0.213
Observations	115	115	115	115	115	119
No. of countries	38	38	38	38	38	38

Notes:
Standard errors clustered at country level in parentheses
*** $p<0.01$,
** $p<0.05$,
* $p<0.1$

Table 6
Gender gap in PISA math test and gender equality measures. Panel analysis (with year and country fixed effects). PISA sample of students above the median of the ESCS of each country.

	(1)	(2)	(3)	(4)	(5)	(6)
GGI	-16.816					
	(29.381)					
GGI*Q1	101.519**					
	(48.858)					
GGI*Q2	9.834					
	(38.873)					
GGI*Q3	-16.903					
	(26.281)					
EOI		-9.771				
		(12.940)				
EOI*Q1		7.477				
		(25.411)				
EOI*Q2		-12.875				
		(19.801)				
EOI*Q3		-10.756				
		(16.436)				
PEI			-3.288			
			(12.542)			
PEI*Q1			48.859**			
			(23.595)			
PEI*Q2			3.394			
			(13.567)			
PEI*Q3			-6.844			
			(9.268)			
Educ.index				-21.363		
				(92.934)		
Educ.index*Q1				151.032		
				(101.322)		
Educ.index*Q2				69.929		
				(99.957)		
Educ.index*Q3				-8.887		
				(104.090)		
Health index					-166.172	
					(115.652)	
Health index*Q1					317.150	
					(195.708)	
Health index*Q2					121.607	
					(193.848)	
Health index*Q3					-54.708	
					(105.854)	
FMLFP ratio						-0.190
						(0.419)
FMLFP ratio*Q1						0.107
						(0.477)
FMLFP ratio*Q2						-0.060
						(0.445)
FMLFP ratio*Q3						-0.457
						(0.354)
Q1	-68.669**	-5.480	-6.378	-150.018	-312.381	-2.746
	(33.588)	(16.799)	(4.428)	(100.854)	(191.510)	(37.568)
Q2	-4.922	9.564	1.125	-68.873	-118.695	10.163
	(27.256)	(13.534)	(3.171)	(99.572)	(188.937)	(35.279)
Q3	14.530	9.569	4.000	10.478	54.794	39.389
	(19.660)	(12.168)	(2.900)	(103.549)	(102.706)	(29.439)
Constant	2.506	-2.965	-8.498***	13.337	154.412	0.692
	(20.834)	(9.301)	(3.001)	(92.314)	(113.269)	(33.580)
R-squared	0.141	0.125	0.139	0.144	0.122	0.152
Observations	281	281	281	281	281	285
No. of countries	72	72	72	72	72	72

Notes: Standard errors clustered at country level in parentheses
*** $p<0.01$,
** $p<0.05$,
* $p<0.1$Q1, Q2 and Q3 are dummy variables corresponding the the 1st, 2nd and 3rd quartile of the distribution of the GDP pc in PPP of each country in the sample (Q4 is the reference category). Estimations using PISA2003-2015.

Table 7
Gender gap in PISA math test and gender equality measures. Panel analysis (with year and country fixed effects). PISA sample of all students

	(1)	(2)	(3)	(4)	(5)	(6)
GGI	-6.970					
	(24.985)					
GGI*Q1	96.193**					
	(42.528)					
GGI*Q2	22.400					
	(39.673)					
GGI*Q3	-33.039					
	(23.609)					
EOI		-8.982				
		(12.477)				
EOI*Q1		11.240				
		(23.514)				
EOI*Q2		-10.465				
		(22.698)				
EOI*Q3		-25.472				
		(16.267)				
PEI			1.078			
			(10.485)			
PEI*Q1			30.298			
			(19.082)			
PEI*Q2			8.262			
			(12.991)			
PEI*Q3			-10.204			
			(7.843)			
Educ.index				1.733		
				(71.812)		
Educ.index*Q1				89.993		
				(76.241)		
Educ.index*Q2				35.553		
				(77.795)		
Educ.index*Q3				-105.950		
				(79.950)		
Health index					-138.260	
					(114.958)	
Health index*Q1					487.117***	
					(155.197)	
Health index*Q2					268.668	
					(333.039)	
Health index*Q3					-140.687*	
					(74.508)	
FMLFP ratio						-0.151
						(0.372)
FMLFP ratio*Q1						0.181
						(0.403)
FMLFP ratio*Q2						-0.037
						(0.411)
FMLFP ratio*Q3						-0.535*
						(0.302)
Q1	-64.893**	-6.964	-4.794	-90.375	-479.422***	-8.569
	(29.002)	(15.651)	(4.002)	(76.003)	(151.693)	(31.472)
Q2	-15.338	6.990	-2.198	-37.124	-265.585	6.205
	(27.585)	(15.547)	(3.590)	(77.461)	(325.282)	(32.114)
Q3	24.967	18.634	3.319	105.245	136.562*	44.107*
	(17.642)	(11.815)	(2.755)	(79.487)	(71.841)	(25.124)
Constant	-2.992	-2.746	-7.376***	-7.909	129.868	-0.114
	(17.551)	(8.757)	(2.719)	(71.510)	(112.261)	(29.321)
R-squared	0.149	0.133	0.135	0.144	0.143	0.159
Observations	283	283	283	283	283	287
No. of countries	72	72	72	72	72	72

Notes: Standard errors clustered at country level in parentheses
*** $p<0.01$,
** $p<0.05$,
* $p<0.1$Q1, Q2 and Q3 are dummy variables corresponding the the 1st, 2nd and 3rd quartile of the distribution of the GDP pc in PPP of each country in the sample (Q4 is the reference category). Estimations using PISA2003-2015.

Table 8
Tests of sum of coefficients from Table 6 and Table 7

	Table 6 (Sample of students above the median of ESCS of each country) Summ of coeff.	Table 7 (Sample of all students) Summ of coeff.
GGI + Q1 * GGI	84.702*	89.223**
	(48,398)	(41,944)
EOI + Q1 * EOI	-2.294	2.258
	(23,403)	(22,087)
PEI + Q1 * PEI	45.571**	31.377*
	(22,407)	(17,771)
Educ.index + Q1 * Educ.index	129.669***	91.726***
	(45,796)	(31,318)
Health index + Q1 * Health index	150.978	348.858***
	(171,290)	(110,984)
FMLFP ratio + Q1 * FMLFP ratio	-0.083	0.029
	(0,258)	(0,212)

Notes: Standard errors in parentheses.
*** $p<0.01$,
** $p<0.05$,
* $p<0.1$

sample of students (see Table A2 in the Appendix[13]) rather than the sample of students in the upper half of each country socioeconomic status distribution as in Guiso *et al.* (2008) and our benchmark analyses.

3.2. Controlling for PISA cohort/time differences

In Table 4, we modify Guiso *et al.* (2008) model to add year fixed effects (δ_t) with the purpose of accounting for PISA cohort differences and/or time variation. We estimate the new model - see equation (2) below - using the same country groups and measures of female emancipation as in Table 3.

$$Y_{it} = \alpha_1 + \alpha_2 GE_{it} + \alpha_3 \log GDP_{it} + \delta_t + \varepsilon_{it} \tag{2}$$

This change delivers the same qualitative results as in Table 3: the relative under-performance of girls in math test scores generally significantly decreases with gender equality across OECD countries. However, no positive relationship is apparent between gender equality and the female-male gender gap across non-OECD countries after controlling for time/cohort effects. This result also holds when using the full sample of students regardless of their socioeconomic status as shown in Appendix Table A3.

3.3. Controlling for time-invariant unobserved heterogeneity at the country level

Even though all the models estimated so far control for the countries' level of economic development by including the log of the GDP per capita as an explanatory variable, it is plausible that previous results are due to the presence of country-level unobserved factors potentially affecting both the math gender gap and our gender equality indicators. To address this concern, in Table 5 we estimate model (3), which adds country fixed effects (δ_i) to model (2):

$$Y_{it} = \alpha_1 + \alpha_2 GE_{it} + \alpha_3 \log GDP_{it} + \delta_t + \delta_i + \varepsilon_{it} \tag{3}$$

Doing so implies that we are now eliminating the influence of time-invariant country-specific characteristics by exploiting changes in gender equality within each country over time to identify the effect of gender equality indicators on the math gender gap. The analysis is again shown for the Guiso *et al.* (2008) sample (Panel A), OECD countries (Panel B), and non-OECD countries (Panel C) for the period 2003-2015.

The comparison of Column 1 of Panel A in Tables 3, 4, and 5 reveals that including country and year fixed effects changes the sign of the estimated coefficient of the GGI, which is now negative, considerably smaller in absolute value, and no longer statistically significant. Note also that Guiso *et al.*'s (2008) estimated effect of the GGI does not fall within our 95% confidence interval. This indicates that, once we account for country-specific time-invariant idiosyncrasies, the positive and statistically significant association between the GGI and the math gender gap in the sample of countries used in Guiso *et al.* (2008) vanishes. The same conclusion is generally reached if we focus on OECD countries (Panel B) —which is to be expected as Guiso *et al.* (2008) sample consisted mostly of OECD countries[14]—, and if we use alternative indicators of gender equality (Columns 2-6).

In sum, findings from Table 5 reveal that results from cross-sectional analyses no longer hold once country-specific unobserved determinants of the math gender gap are accounted for, both in the sample of countries used in Guiso *et al.* (2008) —most of which belong to the OECD— and in the sample of OECD countries currently available in PISA over the 2003-2015 period.

As for non-OECD countries, results from Panel C in Table 5 yield the same conclusion obtained when previously estimating equations (1) and (2) in Panel C of Tables 3 and 4, respectively: there is no positive and significant association between gender equality and the female-male math gender gap. Appendix Table A4 shows similar results for the full sample of PISA students.

3.4. Non-linearities

Non-OECD countries are on average poorer than OECD countries, but using GDP per capita to group countries according to their level of development is likely more accurate and may allow us to dig deeper into the different pattern of results between OECD and non-OECD countries. In particular, we have estimated our preferred model (with country and year fixed effects) including different gender equality measures on the right-hand side as well as GDP per capita quartiles and their interactions with the gender equality indicators. That is, we estimate the following equation:

$$Y_{it} = \alpha_1 + \alpha_2 GE_{it} + \sum_{j=1}^{3} \gamma_j GE_{it} * Q_{jit} + \sum_{j=1}^{3} \delta_j Q_{jit} + \delta_t + \delta_i + \varepsilon_{it} \tag{4}$$

where Y_{it} is the math gender gap of country *i* at time *t*, GE_{it} is one of our gender equality indicators (the global GGI, the four subindexes of the GGI and the FMLFP ratio) and Q_{jit} is a dummy variable which takes the value 1 if the GDP per capita in PPP of country *i* at time *t* is in the *jth* quartile (the reference category is the 4th quartile, where GDP per capita in PPP is above the 75th percentile). δ_t are year fixed effects and δ_i are country fixed effects.

These regression results are displayed in Tables 6 and 7 for the sample of students whose socioeconomic status is above the median and for the full sample of students, respectively. We find that, when using two of our gender equality indicators (the overall GGI and its Political Empowerment subindex when using the sample of students above the median of ESCS, and the overall GGI and its Health subindex when using the full sample), their effect on the female-male math gender gap is significantly larger in countries at the bottom quartile of the GDP distribution than in their fourth quartile counterparts.

Additionally, in Table 8 we report the effect of our gender equality

[13] Note that when we use the sample of all students, the total number of observations increases by two. In this sample there is one country (Albania) which has two more observations - for the years 2012 and 2015 - with respect to the case when we use only the sample of students who are above the median of the ESCS. For this country, the ESCS is not available for these two years (2012 and 2015), therefore we cannot include them in the estimations.

[14] 29 countries in the sample of Guiso *et al.* (2008) are OECD country, which is about 75% of their total sample.

indicators on the female-male math gender gap for countries in the bottom quartile of the GDP distribution (that is, we display $\widehat{\alpha_2} + \widehat{\gamma_1}$ and their associated standard errors). We find that the estimated effects are significant and positive in the poorest countries of our sample when using the GGI, as well as its Political Empowerment and Education subindexes (and when using its Health subindex if we do not restrict the sample to students whose ESCS index is above the median).

In sum, we find that, on average, gender equality is not significantly associated with the female-male gender gap once time-invariant unobserved heterogeneity is accounted for (as discussed in Section 3.3). However, non-linear effects are relevant, as we also find that gender equality is significantly and positively associated with the female-male math gender gap in countries at the bottom of the GDP per capita distribution.[15]

4. Robustness checks

4.1. Controlling for student-level heterogeneity

One potential concern with the country-level analyses presented so far is that they may mask systematic differences in student characteristics across countries that could be driving the results. To control for student-level (and not just country-level) heterogeneity, we reran our regressions at the student level and used multilevel models. Level 1 observations (students) are treated as nested within Level 2 observations (countries), and we allow Level 1 effects to vary across countries and over time. In the first level, we estimate equation (5) separately for each country i and year t across j students:

$$Math\ Test\ Score_j = \beta_1 + \beta_2 Female_j + \beta_3 X_j + \mu_j \tag{5}$$

where the left-hand-side variable is student j's math test score, and the main covariate is a female dummy equal to 1 if the student is as female and 0 otherwise. In addition, we include a vector of covariates, X_j, that controls for whether student j is at grade level, the student's age as well as his or her mother's and father's education level and employment status. In all student-level estimations, each observation is weighted using the students' final weights provided in PISA. Hence, $\widehat{\beta}_{2it}$ is the average adjusted math gender gap in country i and year t.

In Level 2 analysis, we regress the estimated coefficient on the female dummy from Level 1, $\widehat{\beta}_{2it}$, on the country-and-year-level variables previously used:

$$\widehat{\beta}_{2it} = \alpha_1 + \alpha_2 GE_{it} + \alpha_3 \log GDP_{it} + \delta_t + \delta_i + \varepsilon_{it} \tag{6}$$

Consistent with our previous evidence, this analysis confirms that, on average, gender equality is not significantly associated at standard levels of testing with the female-male gender gap once time-invariant unobserved heterogeneity as well as student-level observed heterogeneity are accounted for (see Appendix Table A5).

Next, we estimate equation (7) in order to check whether our previous results on non-linearities still hold when controlling for student-level heterogeneity:

$$\widehat{\beta}_{2it} = \alpha_1 + \alpha_2 GE_{it} + \sum_{j=1}^{3} \gamma_j GE_{it} * Q_{jit} + \sum_{j=1}^{3} \delta_j Q_{jit} + \delta_t + \delta_i + \varepsilon_{it} \tag{7}$$

Also, in line with our previous results, we find that the effects of several gender equality indicators (the overall GGI as well as its political and educational subindexes) on the female-male math gender gap are significantly larger in countries at the bottom quartile of the GDP distribution than in their fourth quartile counterparts. As for the estimated effects of our gender equality indicators on the female-male math gender gap for countries in the bottom quartile of the GDP distribution (that is, $\widehat{\alpha_2} + \widehat{\gamma_1}$), we find that they are indeed significant and positive in the poorest countries of our sample when using the GGI, as well as its Political Empowerment, Education and Health subindexes (Appendix Table A6) while controlling for student-level observed heterogeneity.

4.2. Reading test scores

Previous studies have investigated whether gender equality (Guiso *et al.* 2008) and gender social norms (Rodríguez-Planas and Nollenberger 2018) are associated with the gender gap in academic performance more broadly by looking into the gender gap in reading test scores.

Note that the gender gap tends to be reversed in reading with girls outperforming boys (see Column 4 in Appendix Table A1). Table 1 shows that girls over-perform boys in reading by about 30 points on average both in OECD and in non-OECD countries, respectively.

Guiso *et al.* (2008) found that in countries with more gender equality the female-male reading gap is larger. In contrast with this finding, and in line with our previous results for math test scores, we find that, on average, gender equality is not significantly and positively associated with the female-male gap in reading test scores once unobserved permanent heterogeneity is accounted for.[16]

Next, we assess whether the non-linearities we uncovered for math test scores expand to reading by estimating model (4) using reading test scores as the dependent variable. In Appendix Table A7, we report estimates of $\widehat{\alpha_2} + \widehat{\gamma_1}$, as well as their associated standard errors, that is, the estimated effects of our gender equality indicators on the reading gender gap for countries in the bottom quartile of the per capita GDP distribution.

In contrast with the non-linearities uncovered for math test scores, it appears that more gender equality is in general not associated with a significant widening of girls' comparative advantage in reading, neither on average, nor in countries in the bottom quartile of the GDP distribution (as shown in Appendix Table A7). In sum, the significant association we uncover between gender equality and the gender gap in tests performance in poorer countries is limited to mathematics scores. This indicates that the domains of gender equality captured by the GGI and its component are relevant for the math gender gap in poorer countries, but this is not the case for the gender gap in reading. While we cannot rule out that the gender gap in reading achievement may be associated with other aspects of societal gender inequality or by the non-permanent component of gender social norms,[17] our evidence suggests that the gender gap in math performance in poorer countries may be particularly responsive to gender equality in the education and political empowerment domains (see Table 8).

[15] In Tables 3 to 5, the coefficient on the Health and Survival subindex often has a negative sign (the opposite of what one would expect, and the opposite of what generally happens with the other subindexes). Note however that: i) coefficient estimates on the Health and Survival subindex are always far from statistically significant at standard levels of testing in our benchmark model, also when we include both country and time fixed effects (Table 5); ii) when we explore non-linearities instead we find that in countries at the bottom quartile of the GDP distribution the association between Health-related gender equality and the female-male gender gap is, as expected, positive, and statistically significant when we use the full sample of students (Table 7, second column, fifth row).

[16] These results are available upon request from the authors.

[17] For instance, Rodríguez-Planas and Nollenberger (2018) find that the gender gaps in *both* math and reading test scores among second-generation immigrant students are affected by country-of-ancestry gender social norms (as measured by their parents' country of birth GGI). Hence, the gender social norms captured by the GGI likely reflect general rather than math-specific gender stereotypes, therefore affecting the gender gap in several subjects.

5. Conclusion

Our analysis uncovers two important findings regarding the association between gender equality and the math gender gap. First, we find that earlier cross-sectional findings are not robust to controlling for country-specific time-invariant confounding factors. Once we control for time-invariant unobserved country heterogeneity, the positive and significant association between different indicators of gender equality and the relative performance of girls in mathematics (or reading) vanishes in both Guiso *et al.* (2008) original sample (which consisted mostly of OECD countries) and in the 34 OECD countries surveyed by PISA. This could be due to the fact that, as, other authors have suggested, the math gender gap in OECD countries might be more robustly linked to general measures of countries' societal inequalities not directly focused on gender. For instance, Breda et al. (2018) find that the math gender gap is associated with general indicators of societal inequalities (such as income Gini index or the variance in the socioeconomic background of a country's students) that are not directly related to gender. Regarding non-OECD countries, we find no significant and positive association between gender equality and the female-male gender gap regardless of the empirical strategy used.

Second, we also find that the strength and significance of the association between gender equality and the math gender gap varies depending on countries' level of development. In particular, we uncover a positive and significant association between several gender equality indicators and the math gender gap in countries in the bottom quartile of the GDP per capita distribution. Our contrasting results for poorer versus richer countries suggest that policies aimed at narrowing the gender gap in math performance in developing countries should take into account its association with pre-existing gender inequalities especially in the education and political empowerment domains.

Gender equality is negatively associated with GDP per capita, so our findings imply that an improvement in gender equality indicators is associated with a narrowing of the math gender gap in poorer countries, but not in richer countries with higher levels of gender equality. Why is that the case? It could be that, since the gender-neutral goal of subsistence is removed in richer countries, there is more scope for the manifestation of gender-specific ambitions and preferences (Falk and Hermle, 2018). Therefore, greater equality in access to opportunities may not necessarily imply a reduction in the gender gap in preferences towards math and math performance in richer countries. In contrast, the availability of material social resources is limited in poorer countries, where greater gender equality indeed translates into an improvement in girls' relative math performance because the unrestricted expression of preferences crucially depends on the fulfillment of material needs.

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Appendix

Table A1
Average gender gap and averages of gender equality measures

Country	Years in PISA	Average math gender gap	Average reading gender gap	Gender Gap Index	Female/Male labour force participation rate (%)	GDP pc in PPP
OECD countries						
Australia	2003/06/09/12/15	-10.26	33.06	0.72	80.67	40,816.8
Austria	2003/06/09/12/15	-19.61	36.64	0.71	79.70	42,593.8
Belgium	2003/06/09/12/15	-13.00	28.23	0.73	77.31	40,352.4
Canada	2003/06/09/12/15	-11.90	31.09	0.73	85.62	40,942.2
Chile	2006/09/12/15	-20.69	20.10	0.67	60.45	20,076.2
Czech Rep.	2003/06/09/12/15	-8.49	40.27	0.68	74.00	27,429.8
Denmark	2003/06/09/12/15	-11.10	28.03	0.76	86.07	44,401.7
Estonia	2006/09/12/15	-3.49	42.80	0.71	81.07	25,126.8
Finland	2003/06/09/12/15	-4.08	48.78	0.82	87.88	39,034.6
France	2003/06/09/12/15	-11.24	34.34	0.70	81.51	36,815.1
Germany	2003/06/09/12/15	-14.06	36.44	0.76	78.71	40,302.2
Greece	2003/06/09/12/15	-11.66	42.78	0.67	67.54	27,629.1
Hungary	2003/06/09/12/15	-8.17	35.87	0.67	73.59	22,571.7
Iceland	2003/06/09/12/15	7.55	51.08	0.83	88.16	39,745.3
Ireland	2003/06/09/12/15	-13.17	28.66	0.76	72.55	49,267.3
Israel	2006/09/12/15	-10.06	36.48	0.70	82.83	29,648.7
Italy	2003/06/09/12/15	-17.93	35.88	0.67	64.02	36,103.4
Japan	2003/06/09/12/15	-17.32	21.84	0.65	67.12	35,795.6
Latvia	2003/06/09/12/15	-1.40	46.67	0.73	79.97	19,298.4

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Table A1 (*continued*)

Country	Years in PISA	Average math gender gap	Average reading gender gap	Gender Gap Index	Female/Male labour force participation rate (%)	GDP pc in PPP
Luxembourg	2003/06/09/12/15	-15.67	32.09	0.70	74.18	90,202.7
Mexico	2003/06/09/12/15	-9.36	26.05	0.66	53.13	15,678.1
Netherlands	2003/06/09/12/15	-6.70	25.94	0.75	80.41	44,768.0
New Zealand	2003/06/09/12/15	-11.79	33.36	0.77	82.56	32,654.5
Norway	2003/06/09/12/15	-2.85	45.02	0.82	87.66	62,570.8
Poland	2003/06/09/12/15	-7.02	38.94	0.70	75.31	20,704.5
Portugal	2003/06/09/12/15	-10.20	33.38	0.70	81.39	26,417.3
Slovak Rep.	2003/06/09/12/15	-7.88	42.65	0.68	75.16	23,594.9
Slovenia	2006/09/12/15	-2.04	50.03	0.72	82.11	28,477.4
Spain	2003/06/09/12/15	-13.96	29.48	0.73	73.82	32,298.3
Sweden	2003/06/09/12/15	0.38	42.32	0.82	88.94	42,264.0
Switzerland	2003/06/09/12/15	-14.77	33.48	0.74	81.21	54,220.8
Turkey	2003/06/09/12/15	-11.96	36.18	0.60	38.98	18,343.9
United Kingdom	2003/06/09/12/15	-12.26	26.77	0.74	80.87	36,795.5
United States of America	2003/06/09/12/15	-9.22	27.28	0.72	81.48	49,945.3
Non-OECD countries						
Albania	2009	14.54	66.47	0.66	69.57	9,524.6
Algeria	2015	12.04	34.81	0.63	24.94	13,724.3
Azerbaijan	2006/09	-5.14	23.22	0.67	90.37	13,052.5
Argentina	2006/09/12/15	-11.56	38.51	0.71	64.77	18,021.7
Brazil	2003/06/09/12/15	-14.42	31.34	0.67	74.62	13,524.9
Bulgaria	2006/09/12/15	3.67	58.36	0.70	80.31	15,396.8
China	2006/09/12/15	-4.07	28.54	0.68	82.66	9,944.6
Colombia	2006/09/12/15	-19.44	20.41	0.70	66.91	11,296.4
Costa Rica	2012/15	-17.21	24.26	0.73	60.69	14,396.1
Croatia	2006/09/12/15	-10.43	45.68	0.71	76.97	20,463.3
Dominican Rep.	2015	2.75	32.88	0.69	67.11	13,371.5
Georgia	2015	10.47	56.43	0.69	72.76	9,025.1
Hong Kong-China	2003/06/09/12/15	-11.10	28.17	0.67	75.25	45,646.8
Indonesia	2003/06/09/12/15	-0.35	29.11	0.66	61.19	8,217.1
Kazakhstan	2009/12	-1.24	37.84	0.71	86.53	20,491.6
Jordan	2006/09/12/15	11.71	62.74	0.61	21.76	9,090.8
Rep. of Korea	2003/06/09/12/15	-11.84	29.20	0.63	67.72	28,968.8
Kyrgyzstan	2006/09	0.72	50.93	0.69	69.90	2,627.3
Lebanon	2015	-20.25	21.03	0.60	33.34	13,087.4
Lithuania	2006/09/12/15	2.74	53.09	0.72	83.19	22,884.7
Macao-China	2003/06/09/12/15	-7.84	28.45	.	83.18	85,104.3
Malaysia	2012	8.87	39.66	0.65	60.25	22,591.0
Malta	2015	4.76	43.88	0.67	58.07	34,380.1
Montenegro	2006/09/12/15	-3.87	49.59	0.69	82.01	13,859.6
Rep. of Moldova	2015	0.92	50.92	0.74	74.63	4,746.8
Panama	2009	7.73	48.40	0.70	60.75	14,838.6
Peru	2009/12/15	-12.02	22.46	0.69	76.76	10,673.4
Qatar	2006/09/12/15	6.10	53.42	0.62	53.19	120,175.4
Romania	2006/09/12/15	-3.22	37.80	0.68	75.47	18,153.8
Russian Federation	2003/06/09/12/15	-3.33	36.90	0.69	81.33	21,782.9
Serbia	2003/06/09/12	-7.64	42.39	0.70	70.68	11,591.0
Singapore	2009/12/15	-2.32	26.98	0.69	74.73	73,536.4
Viet Nam	2012/15	-3.37	26.60	0.69	89.24	5,288.9
Thailand	2003/06/09/12/15	8.67	46.78	0.69	80.22	12,972.6
Trinidad and Tobago	2009/15	19.08	60.18	0.72	69.88	30,843.6
United Arab Emirates	2009/12/15	0.26	47.65	0.64	44.44	62,302.4
Tunisia	2003/06/09/12/15	-6.67	36.02	0.63	35.35	9,733.5
FYR Macedonia	2015	2.17	40.02	0.70	.	12,759.7

(*continued on next page*)

Table A1 (*continued*)

Country	Years in PISA	Average math gender gap	Average reading gender gap	Gender Gap Index	Female/Male labour force participation rate (%)	GDP pc in PPP
Uruguay	2003/06/09/12/15	-9.74	40.20	0.67	71.90	15,838.9
Total no. of countries	73	73	73	72	72	73
Average		-7.4	36.8	0.7	73.4	31,939.0
Standard deviation		9.2	11.7	0.1	13.6	21,322.2

Notes: Average gender gaps in math and reading are calculated using the PISA sample of students above the median of the ESCS of each country.

Table A2
Gender gap in PISA math test and gender equality measures. PISA sample of all students

Pooled cross-sectional analysis						
Panel A. Guiso et al. (2008) sample	(1)	(2)	(3)	(4)	(5)	(6)
GGI	65.420***					
	(14.743)					
Econ. index		33.877***				
		(8.862)				
PEI			18.749***			
			(5.531)			
Educ. index				38.704*		
				(21.853)		
Health index					-29.313	
					(64.136)	
FMLFP ratio						0.227**
						(0.088)
Log of GDP pc in PPP	-6.194***	-5.178***	-4.991***	-3.006	-2.494	-4.411**
	(1.523)	(1.440)	(1.526)	(1.829)	(1.727)	(1.915)
Constant	7.336	20.991	37.439**	-17.088	44.514	18.823
	(14.318)	(13.393)	(15.811)	(21.465)	(62.285)	(16.202)
R-squared	0.228	0.195	0.164	0.045	0.037	0.112
	184	184	184	184	184	199
No. of countries	37	37	37	37	37	40
Panel B. OECD countries						
GGI	69.040***					
	(14.618)					
Econ. index		36.967***				
		(9.383)				
PEI			20.200***			
			(5.384)			
Educ. index				29.851		
				(22.759)		
Health index					-281.517	
					(302.448)	
FMLFP ratio						0.295**
						(0.117)
Log of GDP pc in PPP	-6.992***	-6.992***	-6.190***	-5.184**	-2.255	-5.573**
	(1.829)	(1.829)	(1.500)	(2.147)	(2.695)	(2.086)
Constant	12.899	29.532*	38.875*	-16.269	290.723	29.510
	(18.827)	(16.415)	(22.207)	(25.206)	(299.447)	(17.924)
R-squared	0.238	0.197	0.173	0.015	0.030	0.162
Observations	166	166	166	166	166	166
No. of countries	34	34	34	34	34	34
Panel C. Non-OECD countries						
GGI	-21.463					
	(52.637)					
Econ. index		5.082				
		(18.459)				
PEI			-31.754			
			(18.973)			
Educ. index				33.830		
				(53.134)		
Health index					-44.096	
					(89.265)	
FMLFP ratio						-0.086
						(0.110)
Log of GDP pc in PPP	2.462	2.658	2.228	2.614	2.440	2.194
	(2.156)	(2.301)	(1.923)	(2.164)	(2.111)	(1.812)
Constant	-13.962	-33.617	-22.235	-63.228	14.432	-20.314
	(45.601)	(27.636)	(19.680)	(55.109)	(84.037)	(19.901)

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Table A2 (*continued*)

Pooled cross-sectional analysis						
R-squared	0.038	0.035	0.078	0.036	0.037	0.042
Observations	117	117	117	117	117	121
No. of countries	38	38	38	38	38	38

Notes: Standard errors clustered at country level in parentheses
*** p<0.01,
** p<0.05,
* p<0.1

Table A3
Gender gap in PISA math test and gender equality measures. PISA sample of all students

Pooled cross-sectional analysis with year fixed effects						
Panel A. Guiso et al. (2008) sample	(1)	(2)	(3)	(4)	(5)	(6)
GGI	64.460***					
	(15.884)					
Econ. index		33.304***				
		(9.564)				
PEI			18.174***			
			(5.778)			
Educ. index				32.287		
				(21.589)		
Health index					-25.265	
					(65.154)	
FMLFP ratio						0.222**
						(0.088)
Log of GDP pc in PPP	-6.168***	-5.144***	-5.018***	-3.061	-2.654	-4.580**
	(1.548)	(1.464)	(1.557)	(1.859)	(1.763)	(1.912)
Constant	8.419	21.783	38.160**	-10.006	42.278	20.716
	(14.635)	(13.601)	(16.041)	(21.697)	(63.166)	(16.307)
R-squared	0.242	0.208	0.184	0.072	0.067	0.153
	184	184	184	184	184	199
No. of countries	37	37	37	37	37	40
Panel B. OECD countries						
GGI	70.187***					
	(16.370)					
Econ. index		38.495***				
		(10.990)				
PEI			19.744***			
			(5.707)			
Educ. index				24.945		
				(22.609)		
Health index					-273.665	
					(306.857)	
FMLFP ratio						0.295**
						(0.122)
Log of GDP pc in PPP	-7.084***	-6.348***	-5.211**	-2.354	-2.676	-6.087***
	(1.856)	(1.505)	(2.181)	(2.735)	(2.513)	(1.756)
Constant	14.119	31.511*	39.842*	-9.994	285.106	31.578*
	(18.773)	(16.145)	(22.301)	(24.728)	(303.817)	(18.047)
R-squared	0.255	0.216	0.189	0.041	0.057	0.186
Observations	166	166	166	166	166	166
No. of countries	34	34	34	34	34	34
Panel C. Non-OECD countries						
GGI	-39.592					
	(54.453)					
Econ. index		3.196				
		(18.495)				
PEI			-45.831**			
			(19.312)			
Educ. index				20.897		
				(51.508)		
Health index					-46.692	
					(88.612)	
FMLFP ratio						-0.077
						(0.111)
Log of GDP pc in PPP	1.866	2.253	1.454	2.234	2.033	1.819
	(2.240)	(2.445)	(1.949)	(2.340)	(2.256)	(1.903)
Constant	-0.313	-32.000	-18.555	-50.172	17.292	-22.185

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Table A3 (*continued*)

Pooled cross-sectional analysis with year fixed effects						
	(46.839)	(27.927)	(19.519)	(56.842)	(82.680)	(20.030)
R-squared	0.098	0.083	0.168	0.084	0.087	0.101
Observations	117	117	117	117	117	121
No. of countries	38	38	38	38	38	38

Notes: Standard errors clustered at country level in parentheses
*** p<0.01,
** p<0.05,
* p<0.1

Table A4
Gender gap in PISA math test and gender equality measures. PISA sample of all students

Panel analysis (with year and country fixed effects)						
Panel A. Guiso et al. (2008) sample	(1)	(2)	(3)	(4)	(5)	(6)
GGI	-26.115					
	(27.438)					
Econ. index		-33.900**				
		(12.570)				
PEI			2.191			
			(10.998)			
Educ. index				34.295		
				(34.748)		
Health index					-113.376	
					(128.991)	
FMLFP ratio						-0.379
						(0.290)
Log of GDP pc in PPP	4.161	0.056	5.054	3.480	5.427	9.720
	(6.594)	(6.251)	(6.562)	(7.073)	(6.556)	(8.117)
Constant	-33.411	11.645	-61.113	-78.459	46.049	-81.428
	(74.801)	(67.150)	(66.914)	(59.198)	(141.722)	(95.236)
R-squared	0.087	0.119	0.081	0.085	0.084	0.150
Observations	184	184	184	184	184	199
No. of countries	37	37	37	37	37	40
Panel B. OECD countries						
GGI	-23.238					
	(25.475)					
Econ. index		-27.241**				
		(12.982)				
PEI			-0.951			
			(9.146)			
Educ. index				34.927		
				(34.301)		
Health index					-182.162	
					(146.643)	
FMLFP ratio						-0.425
						(0.270)
Log of GDP pc in PPP	3.728	0.856	4.245	2.561	5.332	0.783
	(7.881)	(7.655)	(7.989)	(8.623)	(8.247)	(7.962)
Constant	-32.031	-1.347	-53.538	-70.808	112.816	13.455
	(88.628)	(83.233)	(82.882)	(73.337)	(136.820)	(87.295)
R-squared	0.083	0.103	0.078	0.082	0.083	0.106
Observations	166	166	166	166	166	166
No. of countries	34	34	34	34	34	34
Panel C. Non-OECD countries						
GGI	28.606					
	(44.403)					
Econ. index		7.793				
		(16.086)				
PEI			4.101			
			(16.804)			
Educ. index				-31.628		
				(60.558)		
Health index					193.017	
					(140.096)	
FMLFP ratio						0.402
						(0.300)
Log of GDP pc in PPP	-1.027	-0.455	-0.622	0.449	0.779	8.005

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Table A4 (*continued*)

Panel analysis (with year and country fixed effects)						
	(7.609)	(7.757)	(7.407)	(7.817)	(8.950)	(7.837)
Constant	-15.096	-6.297	-0.325	20.813	-199.971	-110.364
	(77.958)	(74.167)	(70.008)	(83.548)	(184.924)	(82.703)
R-squared	0.153	0.152	0.150	0.152	0.171	0.206
Observations	117	117	117	117	117	121
No. of countries	38	38	38	38	38	38

Notes: Standard errors clustered at country level in parentheses
*** p<0.01,
** p<0.05,
* p<0.1,

Table A5
Gender gap in PISA math test and gender equality measures. Multivel model.

Panel analysis (with year and country fixed effects)						
Panel A. Guiso et al. (2008) sample	(1)	(2)	(3)	(4)	(5)	(6)
GGI	-12.831					
	(26.620)					
Econ. index		-14.006				
		(16.143)				
PEI			-1.213			
			(9.029)			
Educ. index				41.551		
				(41.643)		
Health index					19.906	
					(145.303)	
FMLFP ratio						-0.283
						(0.229)
Log of GDP pc in PPP	11.448*	9.817	11.820*	10.025	11.779*	15.013**
	(6.167)	(6.461)	(6.035)	(6.272)	(5.830)	(7.199)
Constant	-120.130*	-103.598	-132.621**	-155.529**	-151.841	-145.719*
	(70.473)	(71.108)	(61.638)	(57.603)	(164.835)	(84.971)
R-squared	0.100	0.105	0.099	0.104	0.099	0.159
Observations	184	184	184	184	184	199
No. of countries	37	37	37	37	37	40
Panel B. OECD countries						
GGI	-13.542					
	(23.215)					
Econ. index		-1.580				
		(15.406)				
PEI			-5.471			
			(7.107)			
Educ. index				36.285		
				(40.765)		
Health index					46.390	
					(235.818)	
FMLFP ratio						-0.306*
						(0.173)
Log of GDP pc in PPP	7.630	7.745	7.830	6.173	7.671	5.440
	(7.045)	(7.621)	(6.905)	(6.462)	(6.614)	(7.760)
Constant	-82.339	-92.059	-92.756	-112.627	-137.579	-46.671
	(79.266)	(83.925)	(71.610)	(71.100)	(247.742)	(86.878)
R-squared	0.063	0.062	0.065	0.066	0.062	0.077
Observations	166	166	166	166	166	166
No. of countries	34	34	34	34	34	34
Panel C. Non-OECD countries						
GGI	36.413					
	(52.559)					
Econ. index		-4.225				
		(14.059)				
PEI			27.421			
			(24.993)			
Educ. index				8.363		
				(59.483)		
Health index					50.646	
					(111.241)	
FMLFP ratio						0.038
						(0.390)

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Table A5 (*continued*)

Panel analysis (with year and country fixed effects)						
Log of GDP pc in PPP	-9.194	-8.333	-9.979	-8.596	-8.079	2.902
	(7.231)	(7.017)	(6.900)	(7.368)	(7.569)	(9.695)
Constant	52.665	71.317	81.552	63.047	17.270	-42.109
	(65.430)	(63.496)	(64.569)	(72.106)	(164.227)	(106.539)
R-squared	0.197	0.193	0.207	0.193	0.194	0.215
Observations	115	115	115	115	115	119
No. of countries	38	38	38	38	38	38

Notes: PISA sample of students above the median of ESCS of each country.
Standard errors clustered at country level in parentheses.
*** $p<0.01$,
** $p<0.05$,
* $p<0.1$In Level 1, we estimate separate equations for each country i and year j across students. The dependent variable is PISA score and control variables are: a dummy for female, a dummy for different grade, age, level of education and employment status of parents.In Level 2, the coefficient of the female dummy from Level 1 is regressed on country and year level variables, and year and country fixed effects.

Table A6
Gender gap in math. Tests of sum of coefficients from estimation of multilevel model with nonlinearities

	Estimation of sample of students above the median of ESCS of each country Summ of coeff.	Estimation of sample of all students Summ of coeff.
GGI + Q1 * GGI	108.531***	98.871***
	(40,874)	(34,496)
EOI + Q1 * EOI	5.896	13.565
	(21,733)	(19,714)
PEI + Q1 * PEI	61.267***	40.289**
	(21,935)	(19,347)
Educ.index + Q1 * Educ.index	112.060**	90.584***
	(43,956)	(33,557)
Health index + Q1 * Health index	265.155*	345.962***
	(154,822)	(90,351)
FMLFP ratio + Q1 * FMLFP ratio	-0.092	0.041
	(0,158)	(0,149)

Notes: Standard errors in parentheses.
*** $p<0.01$,
** $p<0.05$,
* $p<0.1$

Table A7
Gender gap in reading. Tests of sum of coefficients from estimation of the model with nonlinearities

	Estimation of sample of students above the median of ESCS of each country Summ of coeff.	Estimation of sample of all students Summ of coeff.
GGI + Q1 * GGI	14.659	84.913
	(77,955)	(87,650)
EOI + Q1 * EOI	-27.900	-27.948
	(38,411)	(39,182)
PEI + Q1 * PEI	6.505	47.978
	(32,501)	(36,345)
Educ.index + Q1 * Educ.index	186.669***	85.559
	(44,531)	(58,241)
Health index + Q1 * Health index	-132.221	653.211
	(248,924)	(493,509)
FMLFP ratio + Q1 * FMLFP ratio	-0.078	0.040
	(0,315)	(0,258)

Notes: Standard errors in parentheses.
*** $p<0.01$,
** $p<0.05$,
* $p<0.1$

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.econedurev.2020.102064.

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