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ABSTRACT

The Math Gender Gap: The Role of Culture*

This paper explores the role of cultural attitudes towards women in determining math educational gender gaps using the epidemiological approach. To identify whether culture matters, we estimate whether the math gender gap for each immigrant group living in a particular host country (and exposed to the same host country's laws and institutions) is explained by measures of gender equality in the parents' country of ancestry. We find that the higher the degree of gender equality in the country of ancestry, the higher the performance of second-generation immigrant girls relative to boys. This result is robust to alternative specifications, measures of gender equality and the inclusion of other human development indicators in the country of ancestry. The transmission of culture is higher among those in schools with a higher proportion of immigrants or in co-educational schools. Our results suggest that policies aimed at changing beliefs can prove effective in reducing the gender gap in mathematics.

JEL Classification: I21, I24, J16, Z13

Keywords: gender gap in math, immigrants, gender identity

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1. Introduction

It has been widely documented that teenage boys tend to outperform girls in math tests in many industrialized countries. A recent study using longitudinal data for the US found that by the end of fifth grade, girls had fallen more than 0.2 standard deviations behind boys, which is equivalent to 2.5 fewer months of schooling (Fryer & Levitt, 2010).[1] Using 2003 data from the Program for International Student Assessment (PISA) reporting on mathematic tests scores of 15-year-old students from 40 countries, Guiso et al. (2008) document that "*girls' math scores average 10.5 (or 2 percent) lower score points than those of boys, but the results vary by country: -22.6 in Turkey to 14.5 in Iceland*".[2] Given that mathematical ability has been found to determine field choice for college graduates (Paglin and Rufolo 1990 and Turner and Bowen 1999) and a significant part (between 8 and 20 percent) of the gender wage gap can be explained by choice of major (Machin and Puhani 2003, and Black et al. 2008), understanding the causes behind the divergence in math test scores between boys and girls is the first step towards designing policies that aim to improve the conditions for female workers.[3]

Thus far, the literature has focused on two broad explanations of the mathematics gender gap: the biological versus the environment explanation. On the one hand, some scholars claim that the math gender difference is innate and rooted in

[1]Much of the research documenting gender gap in math scores has been based upon US data. The size of the gap reported depends on the test and time-period. Some recent studies suggest that the average gender gap in math scores among teenagers has been narrowing (Hyde & Mertz, 2009), while others document persisting large differences in the average performance of girls relative to boys (Fryer and Levitt 2010). There is a wide consensus that substantial differences persist at the top of the distribution (Ellison & Swanson, 2010; Hyde & Mertz, 2009) and that the fraction of males to females who score in the top 5 percent of the distribution in high school math has remained constant at two to one over the past 20 years (Xie & Shauman, 2003). Ellison and Swanson (2010) document that the gender gap in secondary school math at high achievement levels is present in every US high school, although the size of the gap varies between schools. Bedard and Cho (2010) review the existing evidence documenting gender gap in math scores in OECD countries.

[2] The gender gap is calculated as the girls' average score minus the boys' average score, whereby a negative gap means that boys over perform girls while a positive gap means that girls over perform boys.

[3] Black et al. (2008) find that between 45 and 53 percent of the gender wage gap among college graduates in the US is explained by age, highest degree and major.

biology, and exists due to genetic (Geary, 1998), hormonal (Kimura, 2000) or cerebral differences (Halpern, 2000). On the other hand, several theories rely on societal factors (including gender differential treatment by teachers, parents' differential expectations on math achievement for girls and boys, and gender differences in expected returns to math skills, among others) as the cause for the math gender gap (see Fryer and Levitt 2010 for a thorough literature review--page 212). An influential article in *Science* using data from 40 countries finds that "*girls' underperformance in math relative to boys is eliminated in more gender-equal cultures*", suggesting the important role of the environment behind the math gender gap (Guiso et al., 2008). Using cross-country data from 41 countries from Trends in Mathematics and Science Studies (TIMMS), Fryer and Levitt (2010) also find support for this hypothesis when Muslin countries or countries with high sex-segregated education are excluded from the sample.[4] However, these studies fail to distinguish between the role of institutional constraints versus culture in influencing the math gender gap. It may be that girls' lower performance in math may be the result of having internalized what constitutes being a girl and behaving according to a girl's gender identity (Akerlof and Kranton 2000).[5] Alternatively, girls may choose to invest less in math than boys (independent on beliefs) because they expect lower labor market returns to math skills given the laws, regulations and labor market institutions in their society (Albanesi & Olivetti, 2009). In this paper, we investigate the extent to which beliefs and preferences (as opposed to institutional constraints) explain the math gender gap. If beliefs and preferences about gender roles are important, policies aiming to alter them early in life would be optimal. By contrast,

[4] Using 2009 PISA data, González de San Román and de la Rica (2012) find a similar relationship across regions within a country (Spain) that constitutes a more homogeneous institutional setting.

[5] Note that girls' actions may be influenced by their own beliefs, or by those of their families or neighbours through the rewards and punishments associated with different actions.

if institutional constraints are most relevant, policies aiming at changing institutions in both the labor market and education system would be preferred.

To examine whether culture can explain gender differences in math test performance, we follow the epidemiological approach fully developed in Fernández and Fogli (2009) and reviewed in Fernández (2011).[6] This approach focuses on second-generation immigrants who are exposed to the same host country's labor markets, regulations, laws and institutions but are also influenced by the different cultural beliefs of their parents. To identify the effect of culture, we estimate whether the math gender gap for each immigrant group living in a particular host country is explained by measures of gender equality in the country of ancestry.[7] For this purpose, we merge 2003, 2006, 2009 and 2012 data from PISA and the 2009 World Economic Forum's gender gap index (GGI), which reflects economic and political opportunities, education and well-being for women in the country of ancestry.[8] Using a data set containing 12,027 second-generation migrants from 45 different countries of ancestry and living in twelve host countries, we show that the same pattern as found by Guiso et al. (2008) is evident between the math gender gap of 15-year-old second-generation migrants and the measures of gender equality in the migrants' country of ancestry. We find that the higher the degree of gender equality in the country of ancestry, the higher the

[6] Using the epidemiological approach, several studies have examined the effect of culture on different socio-economic outcomes, including savings rates (Carroll, Rhee, & Rhee, 1994), fertility and female labor force participation (Antecol, 2000; Fernández & Fogli, 2006, 2009; Fernández, 2007), living arrangements (Giuliano, 2007), the demand for social insurance (Eugster, Lalive, Steinhauer, & Zweimüller, 2011), preferences for a child's sex (Almond, Edlund, & Milligan, 2013) and divorce (Furtado et al., 2013).

[7] We follow Fernández and Fogli (2009) and define culture as "*systematic differences in preferences and beliefs across either socially or geographically differentiated groups*".

[8] This is the same index used by Guiso et al. (2008) and Fryer and Levitt (2010). As we explain in the data section, we are constrained to using contemporary measures of gender equality in the ancestry country because the GGI is only first available in 2006, albeit even then only for a subset of countries. In the robustness section, we use alternative proxies of culture measured in the 1990s, which is closer in time at which the parents left their country of birth.

performance of second-generation immigrant girls relative to boys. Our results suggest that cultural beliefs about gender roles explain a large part of the difference in math performance between girls and boys. More precisely, we find that a one standard deviation increase in the country of ancestry's GGI is associated with a decline in the math gender gap of second-generation migrants of 15 percent. Our results are robust to different (1) specification strategies, (2) the inclusion of a large set of individual, parental and country of ancestry controls, (3) adjustments of standard errors, (4) measures of gender equality and (5) changes in sample criteria.

We find that the effect of culture is mostly driven by immigrant girls. In addition, the transmission is higher among those in schools with a higher proportion of immigrants or in co-educational schools. The former result is consistent with higher intergeneration transmission of culture when ethnic social networks are stronger (Fernández and Fogli 2009 and Furtado, Marcén, and Sevilla 2013 find a similar result), whereas the latter result suggests that gender equality considerations are less important when peer pressure is low, consistent with Fryer and Levitt's lack of finding in countries with same-sex schools and with gender differential responses to competitive testing environments (Niederle & Vesterlund, 2010).

Our contribution to the math gender gap literature is threefold. First, we isolate the role of culture from institutional constraints. Second, we shed some light on a causal interpretation of Guiso et al.'s (2008) and Fryer and Levitt's (2010) findings, showing that the same pattern exists among second-immigration immigrants. Third, we find that heterogeneity matters with the effect of culture being driven by schools with lower proportion of girls and those with a higher proportion of immigrants.

The remainder of this paper is organized as follows. Sections 2 and 3 describe the empirical strategy and the data and sample selection, respectively. Sections 4 and 5 present the main results and the robustness checks, respectively. After presenting evidence on the transmission of culture in Section 6, Section 7 concludes.

2. Empirical Strategy

To distinguish the effect of culture from that of institutions and other environmental factors in explaining variation in math scores between girls and boys, our empirical approach makes use of the fact that all second-generation immigrants have been exposed to the host country´s markets and institutions. Thus, evidence that gender equality in the immigrant´s country of ancestry can explain math scores of second-generation immigrants suggests that the preferences and beliefs of the migrant's ancestors matter and have been transmitted to them by their parents and/or their ethnic community. We use OLS to estimate the following baseline specification:

$$E_{ijkt}=\alpha_1 female_i + \alpha_2(female_i\, GE_j)+ \lambda_j+ \lambda_k+ \delta(female_i\, \lambda_k)+ \lambda_t+ X'_{ijkt}\beta_1+ (X'_{ijkt} female_i)\beta_2 + \varepsilon_{ijkt} \quad (1)$$

where i is the second-generation immigrant whose country of ancestry is j and lives in host country k at time t.[9] E_{ijkt} indicates an individual's educational attainment in math test scores. To identify the differences in educational attainment between sexes, the variable $female_i$ is a dummy equal to one if the individual is a girl and zero otherwise.

[9] Throughout the paper, we will refer to the country where each individual is born and lives as their "host country". Given that they are second-generation immigrants, the country where they were born and live is actually the host country of their parents.

The variable GE_j is a measure of gender equality from the immigrant's country of ancestry, such that a higher value is associated with a more egalitarian culture. Our coefficient of interest on the interaction between GE_j and the female dummy, α_2, captures the role of gender equality in explaining the gender differences in the educational achievement of second-generation immigrant boys and girls. A positive and significant α_2 would suggest that more egalitarian attitudes in the immigrant's country of ancestry are associated with a higher relative performance of second-generation immigrant girls over boys, and thus a smaller gender gap in children educational attainment. Thus, the gender gap in math scores between a boy and girl from a country of ancestry j with more egalitarian gender roles (higher GE_j) would be smaller than the gender gap between a boy and girl from a country of ancestry with less egalitarian gender roles (lower GE_j).

We also include country of ancestry fixed effects (λ_j) to account for characteristics in the immigrant's country of ancestry that may be related to gender roles and educational achievements of second-generation immigrants. We include year fixed effects (λ_t) to account for cohort differences and other time variation. In contrast to previous studies using the epidemiological approach that focus on second-generation immigrants living in one country (in general US or Canada), we need to include host country fixed effects (λ_k) in our specification to account for the host country's characteristics that may be related to educational attainment. Crucially, host country dummies are interacted with the female dummy to account for variation in the host country's educational gender gaps that may arise from cross-country differentials in cultural or institutional channels.

The vector X_{ijkt} includes a set of individual characteristics that may affect educational attainment for reasons unrelated to gender equality, and their interaction with female dummy. In our baseline specification, we only include the age of the child at the time of the exam and a dummy indicating whether the individual is in a different grade from the modal one in the country. Since all additional socio-demographic characteristics that we observe at age 15 are potentially endogenous, we do not include them in our baseline specification (see specification 3 instead).

A second specification further includes GDP per capita (in logarithms) from the immigrant's country of ancestry interacted by the female dummy.[10] Including the interaction between the female dummy and the level of development of the country of ancestry ensures that our coefficient of interest α_2, captures the effect of gender equality and not differences in the level of development that may affect an immigrant's test scores for reasons unrelated to gender equality.[11] Throughout the paper, we will refer to this specification as our "preferred specification".

$$E_{ijkt}=\alpha_1 female_i + \alpha_2(female_i\ GE_j)+ \alpha_3(female_i\ lgdp_j)+ \lambda_j+ \lambda_k+ \delta_1(female_i\ \lambda_k) + \lambda_t+ X'_{ijkt}\beta_1+ (X'_{ijkt}female_i)\beta_2 + \varepsilon_{ijkt} \quad (2)$$

Several sources of heterogeneity across individuals other than cultural beliefs on gender roles may affect their educational attainment. To take this into account, a third specification additionally adds to equation (2) socio-demographic characteristics related to the immigrant's family (vector X) and school (vector *Z)* and their interaction with the

[10] The gross domestic product per capita is expressed in real terms deflated with Laspeyres price index. Source: Alan Heston, Robert Summers and Bettina Aten, Penn World Table Version 7.0, Center for International Comparisons of Production, Income and Prices at the University of Pennsylvania, June 2011.

[11] As a robustness test, we also estimate a specification in which we also control for the Human Development Index (HDI) as proxy of the level of development of the country of ancestry.

female dummy. As family controls, we include the mother's and father's highest educational attainment, two dummy variables indicating whether the mother and father work or not, two indexes indicating the cultural and educational resources at home, and a dummy variable indicating whether the individual speaks a different language at home than the standard in the host country. As school controls, we include the percentage of girls enrolled at school, whether the school is publicly or privately financed, and whether or not the school is in a metropolitan area. Information on how these variables are defined and descriptive statistics are shown in Appendix Table A.1.[12]

Without these controls, α_2 may capture a spurious correlation between the individual's unobserved factors and our measures of gender equality. For example, if more educated mothers increase the test performance of girls relative to boys, and if it is less costly for a girl to perform relatively better in school if her parents come from an egalitarian country, the correlation captured by α_2 would be due to the correlation between parental characteristics by country of ancestry and female education.

$$E_{ijkt}=\alpha_1 female_i+ \alpha_2(female_i\ GE_j)+ \alpha_3(female_i\ lgdp_j)+ \lambda_j+ \lambda_k+ \delta_1(female_i\ \lambda_k) + \lambda_t+ X'_{ijkt}\beta_1+ (X'_{ijkt}female_i)\beta_2 + Z'_{ijkt}\beta_3+ (Z'_{ijkt}female_i)\beta_4+ \varepsilon_{ijkt} \qquad (3)$$

The fourth specification substitutes the interaction between the female dummy and the host country fixed effects in equation (2) by the interaction between the female dummy and gender equality (GE_k) and GDP per capita ($lgdp_k$) in the host country. In

[12] To avoid losing observations due to item non-response in one or several of these questions, we impute the missing values following the MICE method of multiple multivariate imputation described by Van Buuren, Boshuizen, and Knook (1999). This multiple imputation approach is more appropriate when the assumption of random distribution of non-response is dubious. The basic idea is to create a small number of copies of the data (in our case 5), each of which has the missing values suitably imputed. For each imputation, we use the command *mvis* in Stata and control for country of ancestry, year and country of birth. Subsequently, estimates of the parameters of interest are averaged across the five copies to give a single estimate and standard errors are computed according to the "Rubin rules" (Rubin, 1987).

doing so, this specification accounts for the fact that immigrants from countries of ancestry with less gender-equal culture may tend to settle in host countries with similar gender-equal culture and institutions. If this is the case, our coefficient of interest in equation (2) would be biased upwards as it would capture the effect of the host country's culture and institutions, in addition to the effects of culture in the immigrant's country of ancestry.

$$E_{ijk} = \alpha_1\ female_i + \alpha_2\ (female_i\ GE_j) + \alpha_3(female_i\ lgdp_j) + \lambda_j + \lambda_k + \lambda_t + \delta_1(female_i\ GE_k) + \delta_2(female_i\ lgdp_k) + X'_{ijkt}\beta_1 + (X'_{ijkt} female_i)\beta_2 + \varepsilon_{ijk} \quad (4)$$

Because identification in our models comes from the variation of gender equality across country of ancestry, standard errors are clustered at this level.

3. Data and Sample

Program for International Student Assessment (PISA) Data

Our main data set uses the 2003, 2006, 2009 and 2012 student-level data from the *PISA*, an internationally standardized assessment conducted by the Organization for Economic Cooperation and Development (OECD) and administered to 15-year olds in schools every three years since 2000. In contrast to other international assessment, such as TIMSS, which focuses on assessing what students have learned in the classroom, the purpose of PISA is to test whether students have acquired the essential knowledge and skills for full participation in society near the end of compulsory education. These skills include whether they can analyze, reason and communicate effectively. According to the OECD, the PISA math test assesses "*the capacity to identify and understand the role that mathematics plays in the world, to make well-founded judgments and to use and engage with mathematics in ways that meet the needs of that individual's life as a* *constructive, concerned and reflective citizen*" (OECD, 2004, p. 26). Else-Quest, Hyde and Linn (2010) suggest that PISA may be more relevant to measure the math gender gap than TIMMS, because it is a more challenging assessment. Even if we wanted to use TIMMS, the lack of information on the country of ancestry of second-immigrants prevents us from doing so.[13]

PISA assesses a range of relevant skills and competencies in three main domains: mathematics, reading and science. In addition, students and school principals also answer questionnaires to provide information about the students' backgrounds, schools and learning experiences, as well as the broader school system and learning environment. Our analysis focuses on mathematics and begins in 2003 because questions entering the math scores are not comparable before and after that year. PISA tests are paper and pencil tests, lasting up to two hours for each student. Participation in PISA tests is voluntary for schools and students, although a minimum participation rate of 65 percent (80 percent) of schools (students) from the original sample is required for a country to be included in the international database. Each subject is tested using a broad sample of tasks with differing levels of difficulty to represent a comprehensive indicator of the continuum of students' abilities. The PISA program presents the tests scores in standardized form, whereby they have a mean of 500 test-score points and a standard deviation of 100 test-score points across the OECD countries.

PISA uses imputation methods, denoted as plausible values (hereinafter PV), to report student performance. In all of our analysis, we use PV and follow the OECD recommendations that involve estimating one regression for each set of PV (there are

[13] TIMSS is an international assessment of mathematics and science learning in eighth graders, conducted on a four-year cycle by the International Association for the Evaluation of International Achievement (IEA), in collaboration with Statistics Canada and the Educational Testing Service.

five PV to each domain) and subsequently report the arithmetic average of these estimates. In addition, PISA sample is stratified at two stages: first, schools are randomly selected; and second, students at each school are randomly assigned to carry out the test in all three subjects. Our results are robust to applying the Fay's Balanced Repeated Replicated (BRR) methodology, which takes into account this two-stage sample design (as shown in the Results Section).

Gender Equality Measures

To measure gender equality in an immigrant's country of ancestry, we follow Guiso et al. (2008) and use the Gender Gap Index and the Political Empowerment Index (henceforth GGI, PEI, respectively) from the World Economic Forum (Hausmann, Tyson, & Zahidi, 2009). We also use female labor force participation in the immigrant's country of ancestry from the International Labour Organization. All these measures are standard in the literature (Fryer and Levitt 2010; Guiso et al. 2008).

The GGI measures the relative position of women in a society taking into account the gap between men and women in economic opportunities, economic participation, educational attainment, political achievements, health and well-being. The PEI is a sub-index from the GGI and measures the gap between men and women in political participation based upon the ratio women to men with seats in parliament, the ratio of women to men in ministerial level and the ratio of the number of years with a woman as head of state to the years with a man. Both indicators range from 0 to 1 and larger values point to a better position of women in society.

As an additional robustness check, in Section 5 we show that our results are robust to using an index of cultural attitudes towards women from the World Value

Survey (also used in Guiso et al. 2008), and the literacy rate gender parity index.[14] Appendix Table A.2 presents a detailed description of all the gender equality measures used in the analysis, as well as basic descriptive statistics.

Information of GGI and PEI is available beginning from 2006. In this year, 115 countries were included in the indexes, 128 in 2007, 130 in 2008 and 134 in 2009. In order to maximize the number of countries in our sample, we focus on 2009 values for all our gender equality indicators in the immigrant's country of ancestry. The use of contemporaneous measures of gender equality rather than those observed at the time parents migrate is a common practice in the literature. First, it is reasonable to expect that countries' aggregated preferences and beliefs about the role of women in society change slowly over time. Second, as Fernández and Fogli (2009) point out, "*one could argue that the values that parents and society transmit are best reflected in what their contemporaneous counterparts are doing in the country of ancestry*". Rather than trying to solve this debate on theoretical grounds, we take an empirical approach and also check the robustness of our results to using proxies of gender equality measured in the 1990s (shown in the Results Section).

Sample

Following the literature, our sample comprises second-generation immigrants who were born and reside in a participating host country but whose parents (both of them) were born in another country. We pool the 2003, 2006, 2009 and 2012 PISA waves to have the larger variation possible in terms of both host countries and countries of ancestry.

[14] We use the 1990-94, 1995-99 and 1999-2004 waves of the World Value Survey and the 1999 data of the literacy rate. Unfortunately, these two variables are missing for many countries, thus precluding us from using them as main indicators.

To determine the students' country of ancestry, we need specific information on their parents' country of birth. This question is not consistently asked among participating countries. For instance, when asking about the country of origin, the US only provided the options "United States of America" and "another country". Consequently, only data from those participating countries providing detailed information about the parents' birth place were used in the analysis.[15] Based upon Blau et al. (2013), who find that the effect of mother's country of origin on second-generation immigrants girls tend to be stronger than the effect of the father's country of origin when parents come from different countries, we assign the mother's country of origin.[16] We restrict our sample to those individuals for whom we observe gender equality measures for both their country of ancestry and their host country, focusing our analysis on host countries with immigrants from at least four countries of ancestry to ensure that we do not compromise the identification in our model, which arises from variation in the gender equality in the immigrant's country of ancestry within a given host country.[17] We also drop second-generation immigrant children whose country of ancestry has fewer than five observations in a given host country.[18] In the robustness section, we explore the robustness of our results to changes in sample criteria.

[15]These are Australia, Austria, Belgium, Denmark, Finland, Germany, Greece, Latvia, Liechtenstein, Luxembourg, New Zealand, Norway, Portugal, Switzerland and Scotland in 2003, 2006, 2009 and 2012 PISA; Argentina, Czech Republic, Israel, Netherlands and Qatar in 2009 and 2012 PISA; and China, Costa Rica and Turkey in 2012.

[16]In any case, 85 percent of the second-generation immigrants in our sample have parents who emigrate from the same country.

[17]The lack of gender equality measures for all countries implies losing the following countries of ancestry: Afghanistan, Bosnia and Herzegovina, Cape Verde, Occupied Palestine, Iraq, Lebanon, Liechtenstein, Netherlands Antilles, Somalia, Somoa and Serbia-Montenegro (4,345 observations) and the host country of Liechtenstein (or 135 observations). In any case, most of the countries of ancestry we lose are from conflictive zones, which are commonly excluded from this kind of analysis (see Fernández and Fogli 2009, and Furtado, Marcén, and Sevilla 2013). In addition, by limiting our analysis to host countries with at least four different groups of immigrants we lose 3,983 observations from the following ten host countries (Costa Rica, China, Denmark, Germany, Greece, Latvia, Norway, Portugal, Qatar and Turkey), and seven countries of ancestry (Brazil, Bulgaria, Belarus, Jordan, Egypt, Nicaragua and Yemen).

[18] This is a common practice in the literature. For instance, Fernández and Fogli (2009) eliminate those countries of ancestry with fewer than 15 observations. Given that our regressions are run at the individual level, whether we

Our final sample has 12,027 second-generation migrants from 45 different countries of ancestry and living in twelve host countries (as shown in Appendix Table A.3). Host countries are mainly OECD countries, whereas countries of ancestry are from various continents and levels of development. For instance, the countries of ancestry in our sample cover all continents, with many European (24 countries) and some transition economies (Albania, Poland, Russia and Ukraine), several countries in the Americas (Bolivia, Brazil, Chile, Paraguay, Suriname, United States and Uruguay), some in Asia (Bangladesh, China, India, Korea, Malaysia, Philippines and Vietnam), the Middle East (Iran, Egypt and Pakistan), Africa (Ethiopia, Morocco and South Africa) and Oceania (Australia and New Zealand). Second-generation immigrants whose country of ancestry is Portugal, Turkey or Italy represent 47 percent of the sample. Host countries with the highest sample of second-generation immigrants are Australia, Switzerland and Luxembourg (immigrants living in these countries represent 68 percent of the sample).

Descriptive Statistics

Table 1 presents summary statistics of our countries of ancestry's gender equality measures for our sample of second-generation immigrants. Countries of ancestry are ordered from highest to lowest gender gaps in math test scores, measured as the average boy’s minus the average girl’s scores. Panel A shows a large variation in the gender gap in math scores across countries of ancestry. At the bottom 10 percent of the distribution of the math gender gap by country of ancestry, second-generation immigrant girls substantially underperform boys by 62 score points (0.6 standard

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include these small numbers of observations does not affect our results. With this adjustment, we lose only 20 individuals and five different countries of ancestry (Colombia, Czech Republic, Denmark, Panama and Thailand).

deviation), a difference equivalent to about 1.5 years of schooling. At the top 10 percent of the math gender gap distribution, second-generation immigrant girls outperform boys by 34 scores points (0.3 standard deviation), which is equivalent to ten months of schooling. On average, the difference in math score between girls and boys across our sample is -18.29, the equivalent to 5.5 months of schooling. This gender gap in math scores is quite similar to that observed among all second-generation immigrants and natives living in the host countries included in our analysis, and is not too distant from those shown when all countries participating in PISA assessments are considered (see Table A.4).

Panel A also shows the different measures of gender equality by country of ancestry. The GGI takes values between zero and one and averages 0.68 with a standard deviation of 0.06, varying from 0.55 in Pakistan to 0.81 in Sweden. The PEI displays high variation across countries with a minimum of 0.02 in Iran and a maximum of 0.50 in Sweden, averaging 0.16 with a 0.12 standard deviation in the whole sample. FLFP also varies widely by country, moving from 0.16 percent in Iran to over 78 percent in Ethiopia--the average FLFP in the sample is 49 percent with a standard deviation of 12 percent. Panel B shows the cross-country correlation across the different gender equality measures: unsurprisingly, we find that these measures are correlated. The cross-country correlation between the GGI and PEI or the GGI and the FLFP ranges between 0.78 and 0.67, while the PEI and FLFP have a cross-correlation of 0.32.

Figure 1 plots the average math gender gap of second-generation immigrants by country of ancestry (column 1 of Table 1) versus the three measures of gender equality: GGI, PEI, and FLFP (columns 2 to 4 of Table 1). Overall, the raw data show that the more gender equality in the country of ancestry the higher the relative performance in math scores of second-generation immigrant girls with respect to boys. The correlations range from 0.18 to 0.20 percent and are statistically significant at conventional levels (see column 1 in Panel B of Table 1).

4. Main Results

Can Gender Equality Explain the Gender Gap in Math Scores?

Table 2 displays the coefficient on the interaction between the female dummy and gender equality measure in the country of ancestry, α_2, which informs us about the effect of gender equality on the gender gap in mathematics. Each column displays the results estimating the different empirical specifications, while each row displays the results using alternative measures of gender equality in the country of ancestry.

Column 1 in Table 2 shows a positive and statistically significant coefficient on the interaction between the female dummy and gender equality measure, $\alpha_{2,}$ suggesting that the gender gap in mathematics narrows among children whose country of ancestry is one with more egalitarian attitudes towards women. The results are qualitatively the same in our preferred specification shown in column 2, which includes the interaction between the female dummy and the GDP per capita of the country of ancestry as in equation (2). The coefficient of interest, α_2, remains positive and statistically significant. In fact, this coefficient increases in most specifications with respect to the coefficient estimated in column 1, suggesting that not taking into account differences in the economic development of the immigrant's country of ancestry could lead to a downward bias in the estimated effect of gender equality and the gap in math scores.[19]

The magnitude of the coefficient on the interaction between female dummy and gender equality measure, α_2, suggests that gender identity may explain an important part of the variation in the gender gap in mathematics across immigrants from different countries of ancestry. For instance, the coefficient α_2 in the first row of column 2 estimates that an increase in the level of GGI by one standard deviation is associated with a reduction of 6.94 score points in the gender gap in mathematics, the equivalent of a little over 2 months of schooling. It also accounts for a 15 percent of the variation in the gender gap across countries of ancestry.[20] Alternatively, if immigrants from Turkish descent, whose country of ancestry has a GGI of 0.58 and who present a gender gap in math scores of -13.82 score points, were characterized by the mean gender equality (GGI = 0.67), our statistical model would suggest that the mean score performance in mathematics of second-generation Turkish girls relative to boys would increase by 10 score points, thus practically eliminating their gender gap.[21]

Similar results are obtained when we use the other measures of gender equality. According to the second row in column 2 of Table 2, an increase in the level of PEI by one standard deviation (across countries of ancestry) is associated with a reduction in the gender gap in mathematics of 7 score points, representing 15 percent of the variation in the gender gap across different ancestries. When we use the labor force participation

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[19] Guiso et al. (2008) also find that not taking into account differences in the economic development across countries leads to a downward bias of the estimate effect of gender equality in the math gap (Table S4, supporting material on-line).

[20] Using values from Table 1 this effect was calculated as $\frac{(\alpha_2=115.73)*(GGI_{StDev}=0.06)=6.94}{(Gap\ in\ Math_{StDev}=47.51)} = 0.15$

[21] This is calculated as $[GGI_{AVG}\ (0.67) - GGI_{TUR}(0.58) = 0.09] * \alpha_2(115.73) = 10.4$

rate to measure gender equality, we continue to find that the gender gap in math scores decreases with gender equality. The coefficient in rows 3 of column 2 indicates that an increase in the FLFP by one standard deviation is associated with a reduction in the gender gap in math scores of 3.8 score points, which is 8 percent of the variation in the gender gap across ancestries.[22]

Guiso et al.'s (2008) estimated effects of the gender equality measures over the gender gap in math scores using PISA 2003 are 105.49, 29.1 or 45.0 when the GGI, PEI or FLFP indices are used as gender equality measures, respectively. This implies that an increase in the level of each of these measures by one standard deviation is associated with a reduction in the gender gap across countries between 51 and 68 percent, depending on the measure used.[23] While these magnitudes represent about four times our estimates, they are not directly comparable due to the different identification across studies and the data period under analysis. In their analysis, the identification comes from the variation of the level of gender equality across home countries using both natives and immigrants' gender differences in mathematics test scores. In contrast, in our model, identification comes from the variation across country of ancestry *within* host country using *only* second-generation immigrant children. Having said this, we can compare our analysis to what we would have obtained using all individuals and

[22] This is calculated as $\frac{(\alpha_2=31.56)*(FLFP_{StDev}=0.12)=3.79}{(Gap\ in\ Math_{StDev}=47.51)} = 0.08$

[23] The cross-country standard deviation of the GGI, PEI and FLFP in Guiso et al.'s (2008) sample is 0.05, 0.15 and 0.09 respectively. Given the coefficients estimated by the authors, an increase of one standard deviation in the GGI (0.05) implies a reduction of 5.3 score points in the math gender gap, which represent a reduction of 68 percent of the variation in the gender gap across countries in the their sample (the cross-country standard deviation in the math gender gap is 7.74 according to our own calculation using 2003 PISA). Similarly, an increase of one standard deviation in the PEI and FLFP reduces the gap in math scores in 4.4 or 4.1 points or 56 (51) percent of the cross-country variation in gender gap in their sample. Information about standard deviations of each gender equality measure is available in their Supporting Online Material, available at www.sciencemag.org/cgi/content/full/320/5880/1164/DC1. To make their results of FLFP comparable with ours, we divide their FLFP measure by 100 (and also their estimated coefficient).

only exploiting the cross-country of residence variation as in Guiso et al. (2008) with PISA 2003-2012 to obtain an approximation of how much of the math gender gap across countries of residence is explained by culture versus institutional constraints. When we replicate Guiso et al. (2008) using all countries in PISA 2003, 2006, 2009 and 2012, we find that the effect of GGI over the gender gap in math scores is 47.92 (standard error = 0.048), implying that an increase in the level of this measure by one standard deviation is associated with a reduction in the gender gap across countries of 25 percent. Although this is only a back-of-the-envelope exercise, it suggests that the transmission of beliefs and preferences accounts for 60 percent of the total effect.[24]

While the results from Guiso et al. (2008) suggest the important role of a country's culture and institutions (as opposed to biological explanations) in influencing the relative performance of girls in mathematics, our results assess the relative importance of culture versus institutions, suggesting that the former plays an important role in explaining gender differences in mathematics. It is also important to highlight that owing to our identification strategy, we only capture the effect of inter-generationally transmitted culture as opposed to the effect of culture in the host country, and thus our estimates of the effect of culture should be considered as a downward bias of the total effect of culture.

5. Robustness Checks

This section explores the robustness of these results to (1) specification strategies, (2) the inclusion of a large set of individual, parental and country of ancestry controls, (3)

[24] If this back of the envelope analysis is restricted to only host countries included in our analysis, we find a similar result. In particular, we find that the GGI the over the gender gap in math scores is of 26.55 (standard error = 0.036), implying that an increase in the level of each of these measures by one standard deviation is associated with a reduction in the gender gap across host countries of 22 percent.

adjustments of standard errors, (4) measures of gender equality and (5) changes in sample criteria.

Sensitivity Analysis

One concern is that our results may capture educational differences in the country of ancestry rather than differences in gender equality. If those more egalitarian countries also have more advanced educational systems, the effect of gender equality measures on math gender gap would be upward biased. We check this possibility in column 3 of Table 2 by adding the interaction between the female dummy and the Human Development Index (HDI), which in addition to income (as GDP per capita), includes measures of life expectancy and education (such as mean years of schooling and expected years of schooling). As can be seen, adding this variable has little effect when using GGI or PEI, and reduces precision when using FLFP.

As explained in Section 2, without individual controls, α_2 may still capture spurious correlation between the individuals' unobserved factors and our measures of gender equality. To explore whether omitted variable bias is an issue, results from equation (3) are reported in columns 4 and 5 of Table 2 where family and school characteristics are controlled for, respectively. Column 6 includes both family and school covariates. After controlling for the immigrants' family and school characteristics, the coefficient α_2 remains positive and statistically significant.

Column 7 in Table 2 also shows that our results remain practically unchanged when we adopt even a more flexible specification where each year fixed-effect is interacted by the female dummy to allow different math gender gaps by the cohort assessed in different PISA waves.

Columns 8 and 9 in Table 2 evaluate the extent to which our results are biased due to migrants' parents moving into host countries that are similar in terms of gender equality to their country of ancestry. For this purpose, we substitute the interaction between the female dummy and host country dummies with interactions between the female dummy and gender equality measures and log GDP per capita in the host country, as explained in equation (4) and shown in column 8. In terms of gender equality measures, we include the GGI, the PEI, the total FLFP and the labor force participation for women between 35 and 54 years old, which captures the cohort of women with the same age interval as the mothers of the PISA students under analysis. The idea behind including all these host country gender equality measures is to capture as many dimensions of gender equality as possible in the host country. If those immigrants from countries with less gender-equal cultures also tend to settle in host countries with less gender-equal cultures and institutions, our coefficient of interest may capture the effect of the host country laws and institutions rather than the effect of the culture of ancestry. While the results in column 8 are smaller and less precise than those in our preferred specification (shown in column 2), they are consistent with beliefs from the ancestry country explaining the math gender gap. Column 9 shows that the results are also robust to adding the interaction between the female dummy and host country's HDI to the specification in equation (4).

As explained in Section II, all of our estimates are calculated by clustering standard errors at the country of ancestry level. However, due to the double stratification of the sampling design employed by PISA, column 10 of Table 2 shows a specification that applies the Fay's BRR methodology. Again, the results are robust to this alternative adjustment of the standard errors when we use the GGI or PEI indices, although we lose precision with the FLFP.

Alternative Measures of Gender Equality

Table 3 displays the results from estimating our main specification using alternative measures of gender equality. Panel A tests the robustness of our results to the use of gender equality indexes measured in the 1990s. In particular, we use the proportion of seats held by women in national parliaments in 1990-1997, and female labor participation rates in 1990. As can be seen, the effect remains positive in both cases, but it loses significance when using female labor force participation rates measured in 1990. Following Guiso et al. (2008), Panel B checks the robustness of our results to using two alternative proxies of gender equality in the country of ancestry, namely an indicator elaborated from a series of questions about gender roles included in the World Values Survey (WVS) and the literacy rate gender parity index, which constitutes a good proxy of gender inequality in the access to the educational system.[25] In both cases, our main results hold and remain statistically significant. Most importantly, the magnitude of the effect remains consistent with our main findings. In particular, an increase by one standard deviation in each of these gender equality measures is associated with a reduction in the gender gap in mathematics of 5.55, 3.35, 5.87 or 5.89

[25] Both measures are described in Appendix Table A.2. Note that these measures are not available for many of the countries of ancestry in our dataset, precluding their use in main analysis. In the case of the WVS indicator, we lose nine of the 45 countries of ancestry, while with the literacy rate we lose 28 countries of ancestry.

score points, respectively, which accounts for a 12, 7, 11 and 14 percent of the cross-country variation in the gender gap in mathematics.[26]

Changes in Sample Criteria

Table 4 shows that our results are not driven by the main group of immigrants (the Portuguese) or the host country with the largest sample of immigrants (Switzerland)--shown in panels A and B. Panel C shows that the effect remains when only one host country is used (although the coefficient is no longer statistically significant in the case of Switzerland). Furthermore, the fact that our results remain when using alternative measures that are only available for a smaller number of countries of ancestry, as in Panel B of Table 3, represents additional evidence that our results are not sensitive to changes in sample criteria.

6. Cultural Transmission

This section explores how culture is transmitted. We first consider whether the effect of culture on closing the gender gap in math is due to more positive attitudes about the role of women in society increasing a girl's math score, as opposed to decreasing a boy's math score. Exceeding at mathematics is not considered part of a girl's identity. Using a sample of adults and children, Cvencek, Meltzoff and Greenwald (2011) show that 'girls don't do math' is a widespread cultural stereotype.[27] This stereotype works in an asymmetric way, particularly affecting girls who deviate from the norm, as opposed to

[26] Columns 3 and 4 of Table 3 display the cross-country standard deviation of each of these alternative measures and of the math gender gap used to these calculations.
[27] Anecdotally, in 1994 Mattel created a Barbie™ doll that said, "Math is hard."

boys (Spencer, Steele, & Quinn, 1999). This asymmetry has also been shown in studies exploring the impact of teacher's gender on the math performance of girls and boys. For example, Carrell, Page and West (2010) find a differential effect of a professor's gender on the performance of boys and girls. Whereas girls are affected when reminded about the belief that they are not supposed to be good at math when being taught by a male teacher, boys are not necessarily affected when reminded that they are supposed to be good. Similarly, Gneezy, Niederle and Rustichini (2003) present experimental evidence that women's performance in competitive environments substantially decreases when competing against males, while the performance of men in single-sex tournaments is not significantly different than in mixed-sex tournaments.

Table 5 presents the results from estimating equations (1) to (4) separately for boys and girls. As can be seen in Panel A, the effect of gender equality in the country of ancestry on girls' math tests scores is always positive and statistically significant. An increase of one standard deviation of the GGI index increases girls' score in mathematics by 15 points, explaining almost 25 percent of the cross-country variation in girls' test scores.[28] In contrast to what we find for girls, Panel B of Table 5 shows that the effect of culture on boys' math test scores is smaller and not statistically significant. These findings corroborate the asymmetric effect of culture and show that the reduction of the gender gap found in Table 1 as a result from more egalitarian cultural attitudes towards women primarily comes from girls performing differentially better than boys.

In what follows, we further explore the transmission of culture by conducting subgroup analyses. First, Panel A in Table 6 explores the transmission of culture within

[28] The cross-country standard deviation of girl's math tests scores is 61.99, so that 15 divided by 61.99 is equal to 0.242

different types of schools. For example, Booth and Nolen (2012) and Booth (2009) show that school gender peer effects can explain why girls in girls-only school behave more like boys taking on more risks. They also find that college female students attending female-only classes perform better relative to female students attending mixed-sex classes. Here, we test whether the effect of more egalitarian attitudes towards women in the country of ancestry on girls' math scores remains after controlling for school peer effects, as well as whether the effect of culture through peer effects is greater when there is a higher proportion of boys in the school.

In Panel A, we consider the proportion of girls in the school (as recorded by the school's principal) and at single-sex schools (where 95 percent or more pupils are girls).[29] Although the GGI coefficient remains positive and significant after controlling for school gender composition, we find that the effect of culture varies across subgroups. Crucially, the effect of gender equality is not so important for girls with a higher proportion of girls in the school, as shown by the coefficient on the interaction between the GGI index and the proportion of girls in the school (Panel A.1) and the single-sex dummy (Panel A.2). For example, an increase in the GGI index by one standard deviation increases a girl's math test scores by 16 points if attending a co-educational school, whereas the effect almost halves to 9 points when attending a single-sex school. This evidence is consistent with Fryer and Levitt's lack of finding in countries with same-sex schools, and can be rationalized by the fact that girls in single-sex schools do not fear being perceived as different and thus the cultural effect on girls' performance resulting from the beliefs that girls are worse at math than boys is less important. In line with the above literature concerning gender peer effects in schools,

[29] See Appendix Table A.5 for definition and descriptive statistics of these variables.

we also find that more girls in a school or attendance at a single-sex school is associated with higher math scores for girls.

Panel B explores the transmission within local communities by assessing the extent to which culture is more important for second-generation immigrant girls having a greater exposure to the cultural norms in the country of ancestry. Fernández and Fogli (2009) show that the impact of culture appears to be greater for the descendants of those immigrant groups that have a greater tendency to cluster in the same communities.[30] In particular, they argue that an immigrant ethnic network may be crucial for transferring and protecting cultural beliefs, independently of the human capital externalities derived from an immigrant's neighborhood effects (as argued by Borjas 1995). In our context, it is natural to think of an immigrant's network as school communities. In particular, there is evidence that the scores of immigrant children are different depending on the immigrant concentration in the school although the direction of the effect remains unclear (see for instance Jensen and Rasmussen 2011, and Schnepf 2007). Panel B in Table 6 explores the implications for girls' attainment of having more immigrants in the school and whether the effect of culture depends on how many immigrants there are in the school. To this end, we include the concentration of immigrants in the school and its interaction with the culture proxy (GGI) in Panel B.[31]

[30] Although the literature generally refers to immigrant concentration from the same ethnicity, we cannot undertake the analysis by ethnicity at the school level, given that the sample sizes are very small; rather, we use the concentration of immigrants in a given school as a proxy for the concentration of immigrants from the same ethnicity. To the extent that immigrants are different from natives in a systematic way, independently of the ethnicity, this is not a very strong assumption. In any case, note that findings that the transmission of culture is greater among schools with a high proportion of immigrants would underestimate the true effects of the relevance of immigrant ethnic network as transmission of culture.

[31] We follow Schnepf (2007) and calculate the proportion of immigrants in each school from PISA (see Appendix Table A 5). We include both, first and second-generation immigrants and use final student weights included in PISA data. Given that schools and students participating in PISA are chosen randomly, this ratio should be representative.

The estimates presented in column 2 of Panel B show that the culture coefficient remains positive and significant after controlling for the proportion of immigrants in the school. Interestingly, when the interaction between the GGI index and the proportion of immigrants in the school is included in column 3, we see that the effect of culture is higher for those second-generation immigrant students in schools with a higher proportion of immigrants. For example, an increase in the GGI by one standard deviation is associated with an increase of 18 points in the math scores for girls attending schools with a proportion of immigrants one standard deviation above the median (46 percent), which is 4 points higher than the increase experimented for those girls attending schools with the mean proportion of immigrants (34 percent). The coefficient on the proportion of immigrants in the school is negative, suggesting that second-generation immigrant girls perform worse in math the higher the concentration of immigrants.[32]

Panel C explores transmission of gender identity from parents to children, a channel that has been extensively documented in the literature (Bisin and Verdier 2001; and Farré and Vella 2013). Using the 1995–2011 March Current Population Survey and 1970– 2000 Census data, Blau et al. (2013) find evidence of intergenerational transmission of gender roles among the immigrant population from parents to children, and in particular from mothers to daughters in issues related to fertility and labor force participation.

[32] It is important to take into account the fact that immigrants (both first- and second-generation) living in the host countries included in our analysis have on average a lower score in math tests than natives: 470.56 (standard deviation 104.71) versus 490.77 (standard deviation 98.77).

To test the extent to which the effect of cultural norms persist after controlling for mother characteristics and whether there is a different effect of culture depending on mother's characteristics, we include the mother's educational level and the mother's labor status and its interactions with our culture proxy in Panel C of Table 6. In our sample, the proportion of second-generation immigrant girls who have a mother working is relatively high (81 percent), although the mother's educational level is below upper-secondary school on average. Results in Panel C of Table 6 show that the coefficient on culture remains positive and statistically significant after controlling for the mother's characteristics. Similarly, having a mother who works is positively associated with girls' higher math scores. Interestingly, however, the coefficient for the interaction between the GGI and mother's characteristics is not statistically significant. Although the interaction of the GGI index with the mother's work dummy is negative, suggesting that the role of culture in determining a girl's math scores is less important for those girls whose mother is working, the coefficient is not precisely estimated.

6. Conclusion

This paper aims to rigorously disentangle the effects of markets and institutions from the effects of culture in determining gender differences in educational attainment in mathematics. Second-generation immigrants live in the host country and absorb their country of ancestry's culture from their parents and ethnic communities but are exposed to the host country's laws and institutions. We thus interpret the estimated effect of gender equality in the country of ancestry on math scores of second-generation immigrants as evidence of the role of culture.

We find that the higher degree of gender equality in the country of ancestry improves the performance of second-generation immigrant girls relative to boys. In particular, the gender gap disappears among immigrants from more gender-equal cultures. Our results are robust to a battery of sensitivity tests. Our findings are consistent with those of Guiso et al. (2008) and Fryer and Levitt (2010) using cross-country variation in cultural attitudes towards women. Our findings show that the same pattern exists among second-immigration immigrants, highlighting the relevance of culture in explaining the variation in the math gender gap across countries of ancestry.

We also explore the mechanisms through which culture is transmitted. We first show that the effect of culture on closing the gender gap in math is due to more positive attitudes about the role of women in society, increasing a girl's math scores as opposed to decreasing a boy's. We find that whereas the effect of culture on a girl's math test scores is independent of whether the mother works, positive cultural views towards women seem more important in increasing a girl's math record if she attends a school where the concentration of immigrants or the ratio of boys to girls is greater. These results are suggestive of the relevance of schools and peers within the school, as opposed to mothers and daughters within the family. However, we cannot rule out that more egalitarian parents send their children to schools with a higher concentration of immigrants and boys.

Our findings that a more gender-equal culture affects girls' academic achievement with respect to boys yield support for policies that alter the beliefs about gender roles early in life--see for example work on the transmission of preferences from mothers to daughters and sons (Blau et al. 2013; Farré and Vella 2013; Fernández, Fogli, and Olivetti 2004). Our findings may also explain why similar educational systems may have a differential impact on the relative performance on math for girls and boys, as well as pointing to the interplay between culture and institutions as the key factor.

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Table 1. Gender Gap in Math Scores and Gender Equality by Country of Ancestry

PANEL A

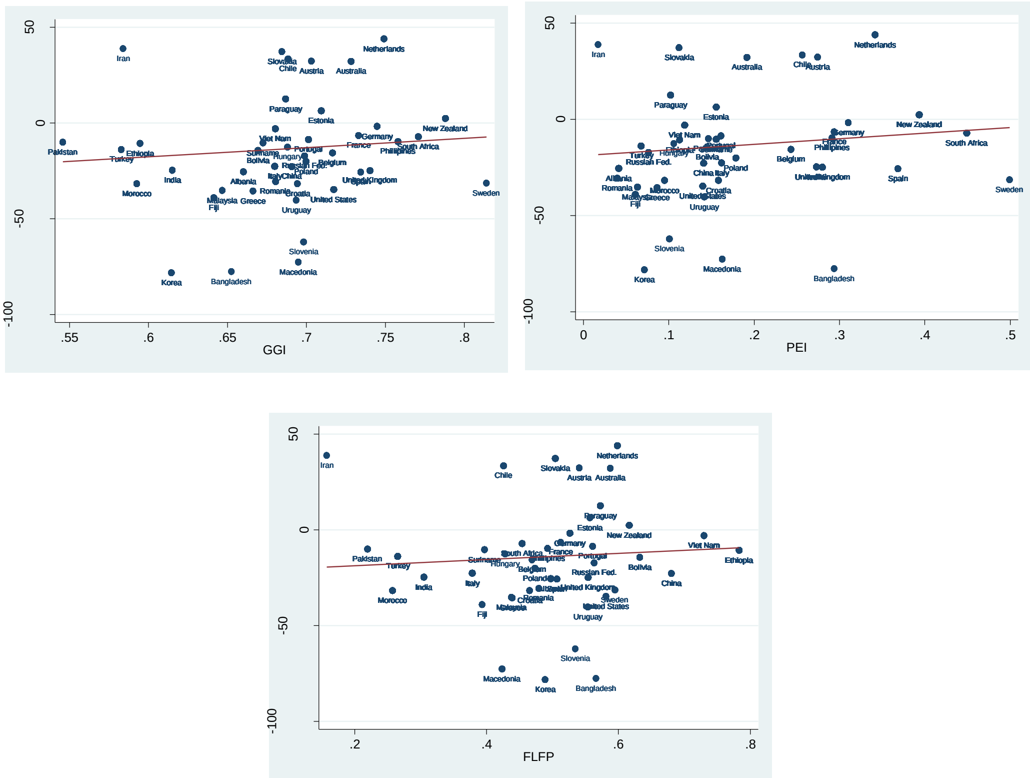
	Country	Math Gender Gap	GGI	PEI	FLFP	*N*
1	Ukraine	-174.97	0.69	0.06	0.53	*5*
2	Korea	-78.24	0.61	0.07	0.49	*46*
3	Bangladesh	-77.60	0.65	0.29	0.57	*7*
4	Macedonia	-72.64	0.69	0.16	0.42	*20*
5	Slovenia	-62.05	0.70	0.10	0.53	*6*
6	Uruguay	-40.31	0.69	0.14	0.55	*17*
7	Fiji	-38.99	0.64	0.06	0.39	*35*
8	Greece	-35.53	0.67	0.09	0.44	*46*
9	Malaysia	-35.19	0.65	0.06	0.44	*34*
10	United States	-34.75	0.72	0.14	0.58	*111*
11	Croatia	-31.74	0.69	0.16	0.47	*77*
12	Morocco	-31.70	0.59	0.10	0.26	*192*
13	Sweden	-31.38	0.81	0.50	0.59	*9*
14	Romania	-30.52	0.68	0.04	0.48	*58*
15	Spain	-25.55	0.73	0.37	0.51	*246*
16	Albania	-25.51	0.66	0.04	0.50	*136*
17	United Kingdom	-24.78	0.74	0.28	0.55	*838*
18	India	-24.71	0.62	0.27	0.30	*168*
19	China	-22.72	0.69	0.14	0.68	*608*
20	Italy	-22.65	0.68	0.16	0.38	*1,083*
21	Poland	-20.11	0.70	0.18	0.47	*47*
22	Russian Fed.	-17.16	0.70	0.08	0.56	*592*
23	Belgium	-15.56	0.72	0.24	0.47	*159*
24	Bolivia	-14.36	0.67	0.15	0.63	*131*
25	Turkey	-13.82	0.58	0.07	0.27	*1,783*
26	Hungary	-12.50	0.69	0.11	0.43	*7*
27	Ethiopia	-10.69	0.59	0.11	0.78	*151*
28	Suriname	-10.39	0.67	0.16	0.40	*107*
29	Pakistan	-9.95	0.55	0.15	0.22	*36*
30	Philippines	-9.66	0.76	0.29	0.49	*240*
31	Portugal	-8.53	0.70	0.16	0.56	*2,846*
32	South Africa	-7.12	0.77	0.45	0.45	*70*
33	France	-6.43	0.73	0.29	0.51	*614*
34	Viet Nam	-2.95	0.68	0.12	0.73	*359*
35	Germany	-1.75	0.74	0.31	0.53	*398*
36	New Zealand	2.42	0.79	0.39	0.62	*376*
37	Estonia	6.35	0.71	0.16	0.56	*55*
38	Paraguay	12.61	0.69	0.10	0.57	*63*
39	Australia	32.26	0.73	0.19	0.59	*36*
40	Austria	32.29	0.70	0.27	0.54	*46*
41	Chile	33.52	0.69	0.26	0.43	*24*
42	Slovakia	37.23	0.68	0.11	0.50	*70*
43	Iran	38.89	0.58	0.02	0.16	*6*
44	Netherlands	43.98	0.75	0.34	0.60	*62*
45	Brazil	180.38	0.67	0.06	0.59	*7*
	mean	-18.29	0.67	0.16	0.49	*12,027*
	sd	47.51	0.06	0.12	0.18	

PANEL B

Math Gap	1				
GGI	0.19*	1			
PEI	0.18*	0.78*	1		
FLFP	0.20*	0.67*	0.32*	1	

Notes: Panel A displays the means of math gender gap and gender equality measures by country of ancestry estimated using our sample of second-generation immigrants from 2003, 2006, 2009 and 2012 PISA. Countries are ordered by the gender gap in math scores. It was obtained from estimating a linear regression using the plausible values provided by the PISA data sets as LHS variable and a female dummy as RHS (we estimated one regression for each PV and present the average of the 5 coefficients estimated). See Appendix Table A.2 for details about gender equality measures. The last two rows of Panel A display the mean and cross-country standard deviation. Panel B display Pearson correlations between variables. *Indicates a correlation statistically significant at 95 percent.

Figure 1. Gender Gap in Math Scores of Second-generation Immigrants and Gender Equality in Countries of Ancestry



Notes: The figure displays the correlation between the average math gender gap among second-generation immigrants and our three measures of gender equality in the country of ancestry. The math gender gap was obtained from estimating a linear regression using the plausible values provided by the PISA data sets as LHS variable and a female dummy as RHS variable. We estimated one regression for each PV for each country and present the average of the 5 coefficients estimated. We use individuals whose both parents were born in a foreign country from the 2003, 2006, 2009 and 2012 PISA datasets. Definitions and data sources of the gender equality measures are presented in Appendix Table A.2. For presentation purposes, Brazil and Ukraine were not included in the figure.

Table 2. Math Scores and Gender Equality

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1. GGI*Female	96.19**	115.73**	132.59**	112.67**	112.35**	109.05**	116.84**	101.15**	97.64*	115.73*
	[41.85]	[44.85]	[52.83]	[50.53]	[44.56]	[50.44]	[49.51]	[45.57]	[48.93]	[61.28]
2. PEI*Female	55.81**	58.31**	57.58**	56.59*	57.32**	55.25*	55.16*	50.03*	49.54*	58.31*
	[27.00]	[26.43]	[25.90]	[30.90]	[25.98]	[30.80]	[27.93]	[27.18]	[27.71]	[34.54]
3. FLFP*Female	30.29*	31.56*	30.97	36.58**	30.49*	35.76**	32.60*	22.41	20.46	31.56
	[16.26]	[16.99]	[18.49]	[16.51]	[16.72]	[16.29]	[18.18]	[14.70]	[15.46]	[23.49]
Observations	*12,027*	*12,027*	*12,027*	*12,027*	*12,027*	*12,027*	*12,027*	*12,027*	*12,027*	*12,027*
Year FE	X	X	X	X	X	X	X	X	X	X
Country of ancestry FE	X	X	X	X	X	X	X	X	X	X
Host country FE	X	X	X	X	X	X	X	X	X	X
Host country FE*Female	X	X	X	X	X	X	X			X
Individuals' age and grade level and its interactions with Female dummy	X	X	X	X	X	X	X	X	X	X
GDP (country of ancestry)*Female		X	X	X	X	X	X	X	X	X
HDI (country of ancestry)*Female			X							
Family characteristics and its interaction with female				X		X				
School characteristics and its interaction with female					X	X				
Year FE*Female							X			
Gender equality (host)*Female								X	X	
GDP (host)*Female								X	X	
HDI (host)*Female									X	
SE adjusted by BRR										X

Notes: Results from estimating equations (1) to (4) on individuals' math scores. Specification (1) includes year, country of ancestry and host country FE, the interaction between host country FE and female dummy, and control for individuals' age and dummies for any students who are in a grade different from the modal one in the country and its interactions with the female dummy. Specification (2), our preferred specification, adds the GDP per capita from the country of ancestry interacted by the female dummy. Specification (3) adds the HDI interacted by the female dummy. Specifications (4), (5) and (6) include family, school characteristics or both and their interaction with the female dummy (see details in Appendix Table A.1). Specification (7) replicate specification (2) but adds the interaction between year FE and female dummy. Specification (8) replaces the interaction between the female dummy and host country FE by the interaction between the female dummy and (i) gender equality measures for the host country (see details in main text) (ii) the host country's GDP per capita. Specification (9) also adds the interaction with the host country's HDI. In specifications (1) to (9), standard errors are clustered at country of ancestry's level, while specification (10) replicates specification (2) adjusting the Standard Error with the BRR methodology. * p<0.1, ** p<0.05, *** p<0.01.

Table 3. Alternative Measures of Gender Equality

		Mean and St.Dev	
	Effect estimated	*GE measure*	*Math Gender Gap*
	(1)	*(2)*	*(3)*
A. Measures from 1990-1997			
Parliament seats held by women (1990-97)*female	85.32***	0.106	-18.21
	[30.07]	[0.065]	[47.23]
N	*12,007*		
FLFP(1990)*female	28.16	0.471	-18.29
	[21.05]	[0.119]	[47.51]
N	*12,027*		
B. Other measures of Gender Equality			
WVS indicator*female	27.97**	2.72	-14.85
	[13.27]	[0.22]	[51.88]
N	*10,949*		
Gap in literacy rate*female	2.12***	99.13	-19.10
	[0.27]	[2.78]	[42.71]
N	*6,797*		

Note: Column (1) displays the results from estimating equation 2 (preferred specification) on individuals' math tests scores using alternative measures of gender equality (see Appendix Table A.2 for details and definition of each measure). Columns (2) and (3) display the mean and cross-country-of-ancestry standard deviation of each measure and the math gender gap, respectively. Standard Errors are clustered at country of ancestry level, which implies 44, 45, 36 and 17 clusters, respectively. * p<0.1, ** p<0.05, *** p<0.01.

Table 4. Sensitivity of Sample Selection

GGI*female (Baseline)	115.73**
	[44.85]
N	*12,027*
A. Dropping the origin with more observations (Portugal)	
GGI*female	110.34**
	[47.57]
N	*9,181*
B. Dropping the host country with more observations (Switzerland)	
GGI*female	111.50**
	[55.00]
N	*9,117*
C. Keeping only one host country	
Switzerland	
GGI*female	163.12
	[106.77]
N	*2,910*
Australia	
GGI*female	199.08**
	[84.98]
N	*2,447*

Notes: Results from estimating equation 2 (preferred specification) on individuals' math scores using different samples of countries of ancestry (Panel A) and host countries (Panel B and C). Standard Errors are clustered at the country of ancestry level, which implies 44, 42, 8 and 14 clusters, respectively. * p<0.1, ** p<0.05, *** p<0.01.

Table 5. Effect of culture of ancestry on girls and boys

Panel A. Girls	**(1)**	**(2)**	**(3)**	**(4)**
GGI	236.31**	253.95**	251.61**	233.36**
	[107.52]	[107.68]	[107.40]	[94.66]
PEI	40.83	17.08	17.15	18.22
	[75.16]	[77.50]	[77.74]	[78.02]
FLFP	134.06**	136.48**	135.32**	116.01**
	[52.84]	[51.72]	[51.50]	[48.38]
N	*6106*	*6106*	*6106*	*6106*
Panel B. Boys				
GGI	157.63	154.82	154.89	140.94
	[121.37]	[128.56]	[127.72]	[119.19]
PEI	-15.08	-45.93	-45.68	-40.74
	[79.98]	[88.94]	[88.32]	[92.24]
FLFP	95.64	101.11*	101.30*	89.97*
	[57.21]	[52.18]	[51.55]	[51.50]
N	*5921*	*5921*	*5921*	*5921*
Year FE	X	X	X	X
Host country FE	X	X	X	
GDP country of ancestry		X	X	X
Individuals' age and grade level	X	X	X	X
Family and school characteristics			X	
Host country Gender Equality and GDP				X

Notes: Results from estimating equations (1) to (4) on girls' and boys' math scores separately. Specification (1) includes year and host countries fixed effects and individual controls. Specification (2) adds the GDP per capita of each country of ancestry. Specification (3) adds family and school characteristics and specification (4) replace host country fixed-effect for host countries' gender equality measures and GDP per capita. Standard errors clustered at country of ancestry level (45 clusters). * p<0.1, ** p<0.05, *** p<0.01.

Table 6. Cultural Transmission

	(1)	(2)	(3)
A. Peer transmission of culture			
GGI	253.95**	252.88**	334.74***
	[107.55]	[107.24]	[111.32]
Proportion of girls		14.16*	127.56**
		[7.14]	[55.71]
GGI*Proportion of girls			-167.58*
			[83.59]
GGI	253.95**	254.16**	265.82**
	[107.68]	[107.83]	[108.97]
Single-sex school		5.06	80.09*
		[6.35]	[44.60]
GGI*Single-sex school			-111.44*
			[67.60]
B. Network transmission of culture			
GGI	253.95**	243.16**	57.00
	[107.68]	[103.52]	[126.53]
Proportion of immigrants		-18.50	-366.23***
		[23.69]	[131.64]
GGI*Proportion of immigrants			529.71**
			[220.40]
C. Mother transmission of culture			
GGI	253.95**	186.82*	248.68**
	[107.55]	[104.99]	[118.40]
Mother's education level		5.23***	-0.56
		[1.53]	[15.64]
Mother work (=1)		14.48**	87.28**
		[6.54]	[40.40]
GGI*Mother's education			8.65
			[23.10]
GGI*Mother work			-111.39
			[69.02]
Year FE	X	X	X
Host Country FE	X	X	X
Individuals' age and grade level	X	X	X

Notes: Column (1) display the results from estimating equation (2) on girls' math scores (column 2 of Panel A in Table 5). In column (2) we also control for: the proportion of girls in the school or a dummy which takes the value of 0 if the girl attend to a single-sex school and zero otherwise (Panel A), the proportion of immigrants in the school (Panel B), or mother's educational level and a dummy indicating whether the mother is working or not (Panel C). Column (3) we add the interaction between these controls and the GGI. See Appendix Table A 5 for definition and descriptive statistics of these variables. We impute missing values in Panel A or C following the MICE method of multiple multivariate imputation. Standard errors clustered at country of ancestry level (45 clusters). * p<0.1, ** p<0.05, *** p<0.01.

Appendix

Table A. 1 Individual-level variables: Definition and Descriptive Statistics

Name	Definition	Mean	St. Dev. across countries of ancestry
A. Individual Characteristics			
Female	Dummy variable equal to 1 if the individual is a girl	0.51	0.11
Age	Years and months	15.77	0.07
Different grade	Dummy equal to 1 if the current individual's grade is different from the modal grade at the children age in the host country and 0 otherwise.	0.38	0.21
B. Family characteristics			
Mother highest level of education (MISCED)	Index constructed by the PISA program based upon the highest education level of each parent. It has the following categories: (0) None; (1) ISCED 1 (primary education); (2) ISCED 2 (lower secondary); (3) ISCED Level 3B or 3C (vocational/pre-vocational upper-secondary); (4) ISCED 3A (upper-secondary) and/or ISCED 4 (non-tertiary post-secondary); (5) ISCED 5B (vocational tertiary); and (6) ISCED 5A, 6 (theoretically-oriented tertiary and post-graduate).	3.42	0.95
Father highest level of education (FISCED)		3.70	0.84
Mother works	Dummy equal to one if the mother (father) works, and zero otherwise. Due to the direct question about parents' labor status is not included in all PISA waves, we use the question about what is the mother (father) main work. The dummy takes the value of zero when the answer is housewife, student or social beneficiary (unemployed, retired, sickness, etc.).	0.82	0.11
Father works		0.96	0.07
Index of cultural possessions (cultposs)	The CULTPOSS index, is based upon the students' responses to whether they had the following at home: classic literature, books of poetry and works of art. These variables are binary and the scale construction is done (by the PISA program) through IRT (item respond theory) scaling. Positive values on this index indicate higher levels of cultural possessions.	-0.30	0.35
Index of home educational resources (hedres)	The index of home educational resources (HEDRES) is based upon the items measuring the existence of educational resources at home including a desk and a quiet place to study, a computer that students can use for schoolwork, educational software, books to help with students' school work, technical reference books and a dictionary. Again, These variables are binary and the scale construction is done through IRT scaling. Positive values on this index indicate higher levels of home educational resources.	-0.07	0.40
Language at home	1 if language spoken at home is different from the test language	0.38	0.26
C. ***School characteristics***			
Percentage of girls	PISA index of the proportion of girls enrolled in each school derived from school principals' responses regarding the number of girls divided by the total of girls and boys at a school.	0.49	0.04
Private school	Dummy equal to 1 if school is private and 0 otherwise.	0.18	0.09
Place of residence	Dummy equal to 1 if the school is in a metropolis and 0 otherwise.	0.14	0.07

Table A. 2 Country-level variables: Definition and Descriptive Statistics

Name	Definition	Mean	St. Dev. across countries of ancestry
A. Gender Equality Measures			
Gender Gap Index (GGI)	Synthesizes the position of women by considering economic opportunities, economic participation, educational attainment, political achievements, health and well-being. The index range between 0 and 1. Larger values point to a better position of women in society. We use the 2009 index. Source: World Economic Forum, 2009 Report.	0.67	0.06
Political Empowerment Index (PEI)	Measure women's political participation based upon three components: (1) the ratio women to men with seats in parliament; (2) the ratio of women to men in ministerial level and (3) the ratio of the number of years with a women as head of state to the years with a man. Larger values point to a better position of women in society. We use the 2009 indexes. This index is also elaborated for the World Economic Forum as part of the Gender Gap Index. Source: World Economic Forum, 2009 Report.	0.16	0.12
FLFP	Female Labor Force Participation, from 15 years old. We use the 2009 rates. Source: International Labour Organization.	0.49	0.12
WVS	Index elaborated from data of the World Value Survey based upon the following questions: (1)"When jobs are scarce, men should have more right to a job than women", (2)"A working mother can establish just as warm and secure a relationship with her children as a mother who does not work", (3)"Being a housewife is just as fulfilling as working for pay", (4)"Both the husband and wife should contribute to household income", (5)"On the whole, men make better political leaders than women do", (6)"If a woman earns more money than her husband, it is almost certain to cause problems" and (7)"A university education is more important for a boy than for a girl". For all but the first, levels of agreements had to be expressed on a scale from 1 to 4. In the first question the answers were "agree," "neither," and "disagree," to which we attributed the respective scores of 1.5, 2.5, and 3.5. We inverted the answers to questions (2) and (4), so that higher values indicate a better position of women in society. The final index is the average by country of the answers to all these questions. We use the 1990-1994, 1995-1998 and 1999-2004 waves. Unfortunately, the 2005-2008 wave does not include most of these questions.	2.63	0.18
Literacy rate GPI	The literacy rate gender parity index (GPI) is the ratio of young female to male literacy rates (ages 15-24). Source: World Bank Statistics; year: 2009. The index range from 0 to 100, and take the maximum value when male and females have the same literacy rate.	97.38	4.26
B. Macro Variables			
GDP per capita	Gross Domestic Product per capita in real terms deflated with Laspeyres price index. We average the 2003, 2006 and 2009 values. Source: Heston, A., Summers, R. and Aten, B, Penn, World Table Version 7.0, Center for International Comparisons of Production, Income and Prices at the University of Pennsylvania, May 2011.	14,721	12,558
Human Development Index (HDI)	The HDI measures the level of development of a country, combining information on people's life expectancies, adult literacy rates, gross enrollment ratios in different educational levels and the GDP. The index range from 0 to 100. Source: http://hdr.undp.org/en/statistics/hdi.	0.74	0.14

Table A. 3 Sample Size by Country of Ancestry and Destiny

		ARG	AUS	AUT	BEL	CHE	CZE	FIN	GBR	ISR	LUX	NLD	NZL	**Total**
1	Albania			4		132								**136**
2	Australia												36	**36**
3	Austria					46								**46**
4	Bangladesh								7					**7**
5	Belgium										159			**159**
6	Bolivia	131												**131**
7	Brazil	7												**7**
8	Chile	24												**24**
9	China		410	3			5	13	20			27	130	**608**
10	Croatia			77										**77**
11	Ethiopia									151				**151**
12	Estonia							55						**55**
13	Fiji												35	**35**
14	France				102	203				67	242			**614**
15	Germany		21	38	41	176					116	6		**398**
16	Greece		46											**46**
17	Hungary			7										**7**
18	India		158						5				5	**168**
19	Iran											6		**6**
20	Italy		88			739					256			**1,083**
21	Korea		31										15	**46**
22	Malaysia		34											**34**
23	Morocco											192		**192**
24	Netherlands		12		50									**62**
25	New Zealand		376											**376**
26	Pakistan								36					**36**
27	Paraguay	63												**63**
28	Philippines		240											**240**
29	Poland			47										**47**
30	Portugal					777					2,069			**2,846**
31	Romania			58										**58**
32	Russian Fed.			3			9	89		491				**592**
33	Slovakia			3			67							**70**
34	Viet Nam		291				68							**359**
35	Slovenia			6										**6**
36	South Africa		60										10	**70**
37	Spain					246								**246**
38	Suriname											107		**107**
39	Sweden							9						**9**
40	Turkey			509	440	591		21				222		**1,783**
41	Ukraine						5							**5**
42	Macedonia			20										**20**
43	United Kingdom		651								14	5	168	838
44	United States		29							82				111
45	Uruguay	17												17
	Total	**242**	**2,447**	**775**	**633**	**2,910**	**154**	**187**	**68**	**791**	**2,856**	**565**	**399**	**12,027**

Notes: Final sample of second-generation immigrants from 2003, 2006, 2009 and 2012 PISA datasets. ARG=Argentina, AUS=Australia, AUT=Austria, BEL=Belgium, CHE=Switzerland, CZE=Czech Republic, FIN=Finland, SCT=Scotland, ISR=Israel, LUX=Luxembourg, NLD=Netherlands, NZL= New Zealand.

Table A. 4 Gender Gap in Test Scores

	All Countries participating in PISA				Countries included in our sample					
	All individuals		Second-generation immigrants		All individuals		Second-generation immigrants		Second-generation immigrants (final sample)	
Math Scores	(1)		(2)		(3)		(4)		(5)	
Boys	459.24	[104.74]	469.95	[94.60]	495.49	[101.89]	492.45	[100.27]	490.96	[109.95]
Girls	446.78	[99.95]	459.77	[92.79]	480.14	[97.37]	475.13	[95.83]	472.67	[99.25]
Gender Gap	**-12.46**		**-10.18**		**-15.35**		**-17.32**		**-18.29**	
N	*1,620,944*		*83,057*		*296,612*		*24,869*		*12.027*	

Notes: Author's calculations based upon 2003, 2006, 2009 and 2012 PISA datasets. Mean and standard deviation in brackets. See Data Section for details about which countries are included in our sample (that is, the host countries included in our analysis).

Table A. 5 School and Mother Characteristics Used in the Analysis of Section 6 over the Sample of Girls: Definitions and Descriptive Statistics

Name	**Definition**	**Mean**	**St. Dev. across countries of ancestry**
A. ***School characteristics***			
Percentage of immigrants	Number of immigrants (either first or second-generation) divided the total individuals by school. Own calculation based upon PISA samples by year, weighted by student final weight.	0.34	0.11
Percentage of girls	See definition in Appendix Table A1.	0.50	0.04
Single-sex school	Dummy equal to 1 if the percentage of girls in the school is higher than 95 percent.	0.10	0.06
Mom work	See definition in Appendix Table A1.	0.81	0.12
Mother highest level of education (MISCED)	See definition in Appendix Table A1.	3.34	1.05