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Culture, institutions and the gender gap in mathematics

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Abstract. PISA, TIMSS and other sources of cross country data show that girls tend to perform better than boys at school, except in mathematics. A school gap in mathematics may imply inequality of opportunities in adult life; wages in sectors of the economy where mathematics is useful tend to be higher than average.
This paper uses data PISA 2006 on 57 countries to analyse several factors potentially correlated to the gender gap in mathematics. We consider variables found to be significant in the empirical literature and some new factors, selecting among them with the use of the Bayesian Information Criterion. Our results are as follows. Religion matters: gaps are narrower in Protestant and Muslim countries and wider in Catholic ones. Job expectations are also robustly significant: girls study relatively more math and get scores nearer to those of boys where they expect to work in their adult life in sectors of the economy where mathematics is useful. Finally, gaps are narrower in ex-communist countries. This may depend on these countries' low rate of religiosity, on school programs and on the role of women in labour markets.

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I. Introduction

The available empirical cross-country evidence shows that school girls tend to perform below boys in mathematics (PISA, TIMSS). The possible causes and consequences of this gender gap in are widely debated. Is it determined by 'nature or nurture' (Penner, 2008); and, if not by nature, how can it be closed? A fact not supporting the biological origin is that - even when individual and aggregate differences are taken into account - the gap depicts a high variability across countries and regions, in some becoming even positive: girls score above boys. Other explanations are based on social factors, culture, norms, the economy. A clear consequence of the gap is unequal opportunity in labour markets.

The base idea of the line of research focusing on culture is that traditional beliefs and feminine prototypes discourage girls from studying math as much as boys, lowering consequently their scores. In the public opinion, math, science and technology can be regarded as fields that require a too strongly competitive behaviour, both during the learning phase and later in the labour market, a behaviour that is not apt for females (Niederle and Vesterlund, 2010). As a proxy of culture, Guiso et al. (2008) use the cross-country index of women' empowerment in society provided by the World Economic Forum, the Gender Gap Index (*ggi*). They calculate the gap in mathematics by using the dataset of the Programme for International Student Assessment (PISA), year 2003, and find the correlation between the two gender gaps to be positive, though not always significant, which suggests that as the role of women in society improves, girls are encouraged to study more math and get more similar scores to those of boys. As the *ggi* tends to be higher in developed countries, it seems to follow that social and economic development are sufficient remedies for the gender gap in mathematics.

The same *ggi* is later tested also with data from Trends in Mathematics and Science Study (TIMSS), year 2003, by Fryer and Levitt (2010), who find that the correlation with the gender gap in math does not hold once some countries of Muslim religion are included into the pool; in them *ggi* levels are low, but girls fare relatively well in math. In the authors' opinion, the result may depend on single-gender classes, which are rather common in Muslim countries: without the presence of boys and the constrain of feminine stereotypes, girls can behave more competitively and get scores similar to those of boys.

Papers focusing on general education, rather than specifically on mathematics, have evidenced the importance of another cultural proxy: religion. A seminal work, by Botticini and Eckstein (2007), show that the Jewish norm ruling since the second century CE that establishes that every Jew should read the Torah improved the level of literacy of Jewish people above historic averages. Later in time, a similar Protestant norm imposing the reading of the Bible boosted the level of literacy among Protestants (Becker and Woessmann, 2008) and, what is more interesting for this paper, reduced the educational gender gap. Norton and Tomal (2009) find the Catholic, Orthodox and Muslim fates to have a negative influence on general education.

The evolution of girls' education during the last century in the US is depicted by Goldin (2006) as intertwined with modifications in the labour market. Girls decided to invest more of their time in education - and in subjects as science and mathematics - when they perceived that in their adult life they could work for themselves, for their own careers rather than for that of their husbands. And they had this perception when the better paid jobs in the labour market, usually those based on technical and scientific knowledge, and the better positions in occupation, began to be concretely available to women. In this case, important changes in technology and political disruptions, as the diffusion of the contraceptive pill or world wars, prompted changes in social roles, in females' education and in labour markets. Several studies discuss about factors related to gender gaps in education and, specifically, in mathematics, across countries or within one country; among these, Niederle and Vesterlund (2010), Baker and Jones (1993), Gneezy and Rustichini (2004), Hyde and Mertz (2009), Machin and Pekkarinen (2008) Pope and Sydnor (2010).

This paper uses data PISA 2006 on 57 countries to empirically investigate the relation between the gender gap in mathematics with the factors seen above – *ggi*, religion, labour markets –

and with other factors of interest, which have been scarcely analyzed in the economic literature. Among these, the attitudes of students regarding the study of math, their expectations regarding future jobs and the communist background of countries.

The data provided by PISA shows that the attitudes of students regarding the importance of studying math and the differences in these attitudes between girls and boys vary substantially between countries. This variation can be related to the general beliefs of people about the significance and usefulness of the advances in mathematical and scientific knowledge; we control for beliefs by using data of World Values Survey. We build a proxy of the expectations of students and the differential expectations of girls and boys regarding their future jobs by using PISA data and by focusing on the sectors of the economy where a technical and mathematical knowledge turns out to be useful.

During the last century, the market, political institutions and schooling institutions of communist and non-communist economies differed markedly. In particular, schooling in communist economies had the double aim of enhancing the level of literacy of the whole population and also, more importantly, of preparing the young to enter a labour force that had to support the rapid industrialization of the economy. Study programs focused on technical, mathematical and scientific subjects and left a minor role to the humanities. Did this affect girls' studies and their performance in math? And, what interest us, do the remains of that schooling system still affect gender gaps? Also, religion in communist countries was banned or strongly discouraged. Did this, in turn, affect education?

Together with the above variables, we consider the hours of math studied by girls and boys, the rates of grades' repetition of the two genders, the average scores in mathematics in countries, their levels of income and growth rates. We proceed by, first, measuring the gender gap in each country, controlling for a number of individual characteristics, and then testing the relation between these gaps and the macro-variables. In this second stage, we use a Bayesian Information Criterion (BIC) to select among regressors.

We find that three main forces are strongly and robustly correlated with the gender gaps in mathematics. First among these is the communist background of countries, it has a positive effect on the relative performance of girls in math. To our knowledge, this is an original result, likely to be related to the schooling and labour market features of the ex-communist economies of our sample, mostly located in Eastern Europe. In the second place, culture matters through its more basic manifestation: religion. In particular, the Protestant religion has a robust and positive influence on the relative performance of girls in math, the effect of the Muslim fate is also positive, while that of Catholicism is negative. In the third place, the expectations of girls of working in the future in jobs where the mathematical knowledge turns out to be useful are also positively and significantly correlated with the gender gaps.

The paper is structured as follows.

II. Econometric specification

The estimation procedure develops in two steps, the first is based on PISA data and measures the difference in scores between girls and boys in each country, the second uses also other sources of data and tests the relations between these gaps and country-wide variables.

4.1 Step one: micro analysis

A linear educational production function is hypothesized, where the output is the scores of students and the inputs are a number of regressors concerning gender, immigration status, a PISA indicator of social status called Economic, Social and Cultural Status (includes parental education, parental occupation and home possessions), *escs*, the grade the student is in, the hours of study of math at school and out of school and the student's opinion about the importance of studying math.

We follow the procedure of Guiso et al. (2008) and Fryer and Levitt (2010) of identifying the gender gap in mathematics with the coefficient of the gender variable in the production function. Among the above regressors, the empirical literature rarely considers the attitudes of students regarding the study of math, despite they can be of interest. We build a proxy of these opinions by using a question of the PISA 2006 Students' Questionnaire (Q36) that reads 'In general, how important do you think it is for you to do well in mathematics?'; answers, of four types, range from 'Very important' to 'Not important at all'. These attitudes are of interest because, at the individual level they can capture a component of performance, talent, that is not measurable directly.[2] At the aggregate level, as country averages, which we will consider in step 2, they are more likely to be related to cultural factors, as people's opinions about the value and usefulness of scientific, mathematic and technical knowledge.

A detailed list of the variables included in the regressions of step 1, country by country is in Table Ax, while complete results are available from the authors upon request. The regression equation is:

$$Y_{ij} = \beta_0 + \beta_G G_{ij} + \boldsymbol{\beta_B B_{ij}} + \boldsymbol{\beta_S S_{ij}} + \beta_D D_{ij} + \varepsilon_{ij} \qquad (1)$$

Y_{ij} is the response variable representing the score obtained by student i in country j in mathematics, G_{ij} is gender, $\boldsymbol{B_{ij}}$ is a vector of background variables, $\boldsymbol{S_{ij}}$ is a vector of grades and hours of study of math, D_{ij} is the importance assigned to the study of math, β_I, $\boldsymbol{\beta}_B$, $\boldsymbol{\beta_S}$, β_D are the respective coefficients, and ε_{ij} is the error term, with $\varepsilon_i \sim N\,(0\,;\,\sigma^2\,)$.

We follow the specific recommendations provided by OECD (2009) for computing parameter estimates and their standard errors by employing the balanced repeated replications (BRRs) (e.g. see Särndal et al., 1992) based on the weights provided in the PISA dataset. BRR is a method to estimate the sampling variability of a statistic that takes into account the properties of the sampling design. Similarly to Jacknife and Bootstrap methods, it uses re-sampling principles and provides unbiased estimates of the sampling error arising from complex sample selection procedures. For our data, BBR accounts for the two-stage sample design for selection of schools

[2] In our case they can help to detect the existence of a systematic difference between genders in the valuation of the importance of studying mathematics that could be related to a difference in talent. To check whether this variable has a significant effect on the gender gap in mathematics we run the country by country regressions first without and then with it.

and students within schools (see OECD, 2009). In particular, PISA provides a set of 80 alternative weights that have to be assigned to each student to form alternative samples at the country level. We employ the BBR weights to estimate the standard errors of regression coefficient as in OECD (2009). Confidence intervals for the inferences are standard (1-α)% confidence intervals (α<0.05) based on the asymptotic normality assumption of the coefficient estimates. We performed diagnostic analysis on the BBR coefficient estimate replicates to confirm that such an assumption is trustworthy for all the reported results. Equation (1) is then estimated with OELS. The coefficients of the gender variable can be interpreted as the 'unexplained' part of gender gaps, the part that remains once individual factors have been taken into account.

4.2 Step two, macro analysis.

At this second stage, the gender gaps mathematics are tested against aggregate, country-wide, factors. Among these, we consider variables often analyzed in the empirical literature and add some new potential explanations.

A shared finding is that education and culture appear to interact. Some studies use religion as a proxy of cultural norms and common beliefs. Botticini and Eckstein (2007) show that the norm ruling since the second century CE that established that every Jew must read the Torah improved the level of literacy of Jewish people above those of populations of other fates. Later, a similar Protestant norm imposing the reading of the Bible boosted the level of literacy of Protestants and, what interest us more, improved the relative education of girls, making it more similar to that of boys (Becker and Woessmann, 2008). Norton and Tomal (2009) confirm the positive effect of Protestantism on schooling and on gender gaps, and find that, instead, the effects of the Roman Catholic, Orthodox and Muslim religions are negative.

Another proxy of culture, which has been used specifically in relation to gender gaps in mathematics, is the empowerment of women in society. Since 2005, the World Economic Forum publishes yearly a cross-country index of women's social empowerment, the Gender Gap Index, *ggi*, which is composed by four sub-indexes: women's levels of education, health and survival, economic participation, and political participation. Guiso et al. (2008) use data of PISA 2003 to measure the gender gap in mathematics and, then, to test their relation with the *ggi*.[3] They find a positive, although not always significant, relation between the two variables: a better relative performance of girls at school appears to be related to a higher empowerment of women in society. Fryer and Levitt (2010) test this relation using also TIMSS 2003 data, and find that it does not hold when Muslim countries are added to the list. These countries rank low in the *ggi* index but, in them, girls tend to perform better than boys in math. In the authors' view, the girls' good relative performance may depend on the use – frequent in Muslim countries- of keeping girls and boys in separate classes and schools: without the presence of boys, girls are not constrained by feminine prototypes and behave more competitively. Following these lines of research, we take into account both proxies of culture, the shares of population belonging to the main religious fates in countries and the *ggi*.

The attitudes of students, and of girls relatively to boys, regarding the importance studying of math can vary across countries. They can be influenced by the general beliefs of people on the significance of the mathematical knowledge and on the usefulness of scientific and technical advances. Using the question 'In general, how important do you think it is for you to do well in mathematics? of the Student's Questionnaire (Q36), this time at the aggregate level, we select the proportions of students in each country responding that math is 'Important' and 'Very important', *math important: all students*, and the differences in these responses between girls and boys, *math important: girls-boys*. Both coefficients should have positive effects. [4]

[3] With the purpose of reducing the heterogeneity in school drop-outs Guiso et al. (2008) use only observations corresponding to the higher 50% percentile of family status, measured in terms of *escs* (Economic Social and Cultural Status). With this procedure, however, relevant information can be lost, hence, we use *escs* as a regressor in step 1 of the analysis. Our final results on the *ggi* coefficient, however, do not depend on it.

[4] To consider the more general position of people on scientific advances, we use a question of the World Values Survey (Q E022; 1981-2002 Aggregated Values Surveys) that reads 'In the long run, do you think the scientific advances we are making will help or harm mankind?'; answers are 'Will help', 'Will harm', 'Some of each'. We select the share of people in each country responding 'Will help' and expect a positive a significant relation between this variable, denoted *wws*, and the attitudes of students regarding the study of math, both at the overall level, *math important: all students*, and as a difference, *math important: girls-boys*.

Institutions may also influence the differential scores of girls and boys. For example, during the last century, the norms, institutions and schooling of the communist economies differed markedly from those of Western countries. One important norm of communist countries banned or strongly discouraged religious practices. Before that era, most of ex-communist countries in our sample were of Orthodox religion, only a few were Catholic or Muslim; hence, following Norton and Tomal (2009), the influence of religion on pre-communist education levels and gender gaps must have been, presumably, negative.

During communism, schooling had the double aim of enhancing the level of literacy of the whole population and, more importantly, of preparing the young to enter a labour force apt to support a rapid industrialization of the economy. A successful technological competition with the West was another, parallel, goal. Study programs focused on technical, mathematical and scientific subjects and left a minor role to the humanities, which were partly substituted by political indoctrination. Technicians and applied scientists were needed, be they males and females.

Consistently, communist governments promoted gender parity in labour markets. As shown in Table 1 below, this group of countries' rate of female participation in the labour force is still high when compared to the sample average, and is high the share of women among professional and technical workers.

Since the end of communism, these countries have gone through relevant changes in society, schooling and work trends. Religiosity is again a free manifestation of social life. Educational reforms are turning the balance of school programs toward the Western model, among other things by giving an increased weight to the humanities and a slightly reduced one to mathematics (cit). There is some evidence that the participation rates of female workers in labour markets are slightly decreasing relatively to that of males (Hartmut Lehman). In this paper we cannot analyse these tendencies nor identify the factors of ex communist countries that may affect the gender gaps in mathematics. We include the *communist background* variable among our regressors and, because of the indirect and incomplete evidence discussed above, we expect its coefficient, if significant, to be positive.

In the economic literature, investments in education and human capital respond to economic incentives: the length of time individuals choose to invest in education depends on expected returns (Becker, 1975). Following the same principle of rationality, for any given length of time, individuals can choose the composition of their investment in terms of subjects of study. If each subject contributes to form a specific human capital to be utilized later in given sectors of the economy, then the composition of the educational investment will depend on the expected wages in those sectors. In this framework, the expectations of students regarding future jobs related to science, technology, engineering, mathematics, *stem* in what follows, can be supposed to affect their choice of studying math, and consequently their scores in the subject. In particular, girls will invest more time and effort in the study of mathematics if they expect this investment to have a positive relative return. We build a proxy of these expectations by using a question of the PISA questionnaire that reads 'What kind of job do you expect to have when you are about 30 years old?' (Q30), and select positive answers concerning the *stem* sectors of the economy.[5] The variable *stem expectations: all students* denotes the share of students expecting to work in these jobs in each country, while the variable *stem expectations: girls/boys* denotes the ratio of girls' to boys' shares. Both coefficients should be positive.

Effective performances in the labour market, especially female participation rates, have been found to be related with girls' length schooling and, in particular, with their choices of studying math and sciences (a review of the literature is in Goldin, 2006). This is consistent with what has been hypothesized above: current jobs may affect the expectations of future jobs, the composition

[5] The selected sectors are: PHYSICAL, MATHEMATICAL & ENGINEERING SCIENCE PROFESSIONALS
PHYSICISTS, CHEMISTS & RELATED PROFESSIONALS
COMPUTING PROFESSIONALS
ARCHITECTS, ENGINEERS ETC PROFESSIONALS
LIFE SCIENCE & HEALTH PROFESSIONALS
Economists
PHYSICAL & ENGINEERING SCIENCE ASSOCIATE PROFESSIONALS & TECHNICIANS

of the girls' educational 'portfolio' and, consequently, their relative scores. We consider the share of female professional and technical workers on total technical workers in each country, *fem prof. tech. workers*, and the ratio between females' and males' labour force participation rates, *labor force p. rate: female/male*, expecting both coefficients to be positive. Of course these relations, if significant, can be spurious or can be affected by a common missing variable. A likely confounding factor is culture: countries with strong feminine stereotypes may be characterized by a girls scoring below boys in math *and* a smaller share of female workers in the labour force or in the strategic sectors of the economy. As seen, however, we include two proxies of culture, religions and the *ggi*, which should obviate for this possibility.

Real time dedicated to study math is of course expected to matter. Because of lack of data, we cannot include the levels of difficulty of the courses of math attended by girls and boys in each country, which would be of great interest for our study, but we can and do consider differential and overall hours of study of the subject: *hours of math: girls – boys*, *hours of math: all students*. Also, the gender gap, which is the coefficient of the gender variable, is not proportional to the average level scores' level of each country; hence we include this variable, in logarithmic form, *ln average test scores*. The per-capita income levels in year 2006, *ln pc_gdp*, are included to control for countries' levels of development. Growth rates can account for structural changes in the economy and denote industrialization processes that, in turn, can concern also school programs and, in particular, girls' attitudes and performance at school. We include the average growth rates of countries' *gdp* during the years 1999 to 2006, *gdp_growth*.

Observations in this second step of the regressions are fifty seven, the number of countries of the PISA 2006 database we take into account, which are too few to test all the above variables simultaneously. Hence, we firstly use the BIC to select regressors from the pool of variables and then run OLS regressions.[6] Furthermore, as for some countries not all figures are available, the

[6] Both backward and forward selection are applied up to the point where taking away (backward) or adding (forward) another regressor from or to the model increases the BIC (e.g. see Burnham and Anderson, 1988). In our analysis, both stepwise search approaches conduct to the same set of selected variables. mode

procedure is repeated five times, with the pool gradually expanding from an initial stage where only variables with no missing data are considered to subsequent stages where all the other regressors included. The general specification of the regression equations is:

$$Gap_j = \beta_0 + \beta \mathbf{Z_j} + \varepsilon_i \qquad (2)$$

where $\boldsymbol{Z_j}$ is a vector of country variables selected with the BIC procedure from the pool of variables and $\boldsymbol{\beta_Z}$ is the vector of coefficients.

III. Data and descriptive statistics

The sources of data are listed in Table A1, while Table 2 depicts the descriptive statistics of some variables of interest. Figures in the first column of Table 2 are un-weighted averages and standard deviations of the whole sample, while those in columns two to four are countries grouped according to religion or communist background. With the exception of Greece, the countries of Orthodox fate belong the group of ex-communist economies, while the number of countries of Jewish, Confucian and Buddhist religions are too low to group them separately.

Gender gaps in math are depicted in the first two rows of the Table; of these, row 1 depicts the gaps obtained by using the dummy *gender* as the only regressor, while row 2 presents the gaps resulting from the multivariate regressions. Gaps are all negative (with different levels of significance): girls' score below boys in all groups of countries. It is worth noticing, also, that the gaps widen in the passage from row 1 to the multivariate regressions of row 2. This suggests that some 'advantage' girls had with respect to boys in the unconditional test is lost with the multivariate regressions. Controlling for the reasons of this increase in absolute values we have found that it depends on two main factors: family background and school grades. Especially in Muslim countries, the average value of *escs*, the index of economic and social conditions, tends to be higher in the sample of girls than in that of boys, indicating that fifteen year-old Muslim girls tend to belong to more well-off families than boys, or that poorer families send girls to school less than they send boys. In most our country regressions the effect of family background on scores is positive and significant. Hence, once the variable *escs* is included into the regressions the absolute value of the gender coefficient increases in several countries, especially the Muslim ones. Similarly, girls tend to repeat grades less than boys. In this case the variable is significant especially in Catholic countries. As before, once the *grade* variable is included into the regression, the negative gap widens, in particular in Catholic countries. In Protestant and ex-communist economies the absolute value of the gender gaps increase because of a combination of these two forces.[7]

Table 1

From now on, we will only consider the gaps resulting from the multivariate regressions, those of row 2, used in the tests with country variables. An interpretation of the measure of gaps is provided by the PISA procedure of standardizing the scores of OECD countries to an average of 500 and an international standard deviation of 100. With this, a school year roughly corresponds to a third of the standard deviation. Hence, on average, girls lag behind boys by about two thirds of a school year; the lag is larger in Catholic countries and substantially lower in the other three groups.

Each group of countries has some well defined traits. Protestant countries are characterized by a high share of students valuing math an important subject of study - but girls tend to value it less than boys -, by above average scores in mathematics, by the highest *ggi* level and by the highest ratio of female to male labour force participation.

[7] Regressions are available upon request. Family background and other variables we take into account are not controlled for in Fryer and Levitt (2010) and in Guiso et al (2008). This may explain the strikingly high relative performance of girls in Muslim countries found by Fryer and Levitt, which in our multivariate regressions vanishes once background is considered.

In ex-communist economies, the share of girls, relatively to boys, that consider the study of math important is higher than in Protestant and Catholic countries; the generality of students - particularly girls – held optimistic expectations of working in the future in the *stem* sectors of the economy; the rate of female professional and technical workers is the highest among the groups considered, and the economies' growth rates are high.

In Catholic countries, where negative gaps are particularly wide, a substantially lower proportion of girls than of boys value math as an important subject of study. Consistently, girls study relatively less hours of math; in absolute value this difference is about 4.5 times larger than in ex-communist countries. Also, a relatively lower proportion of girls expects to work in the future the *stem* sectors of the economy. The female relative presence in labour market is lower than in Protestant and ex-communist economies, both in terms of participation rates and as a share of professional and technical workers. Notwithstanding, as measured by the *ggi*, the social empowerment of women is higher that in ex-communist and Muslim countries.

Finally, in Muslim countries, with respect to boys, proportionately more girls consider important the study of math, girls study relatively more hours of math and expect more than in the other groups to work when adult in *stem* sectors of the economy. These expectations seem to be contradicted the fact that the relative share of women effectively working in these sectors is lower than in the other countries, but this low figure is compensated by an also lower female participation rate in the labour force. Moreover, as mentioned above, fifteen year-old school girls tend to belong to better well-off families than boys, and this can positively influence both their performance at school and job expectations.

Table Ax in the Appendix depicts correlation values between variables.

IV. Results

Results of step 2, regarding the macro variables, are depicted in Table 3. The dependent variable is the gender gap in mathematics in the 57 countries and the regressors, as said above, are selected by the BIC from a pool of variables that expands from a basic stage, from which Model I derives, to the largest one, of Model V. A list of regressors is in the Table's Note.

Our main findings are as follows. The relative performance of girls in mathematics is affected by culture in its more essential manifestation, religion; it is positively influenced by the communist background of countries; and it is also positively correlated with girls' expectations of working in sectors of the economy where the mathematical knowledge is useful. Another cultural factor, the average attitude of students regarding the importance of studying math, is significantly correlated with the gender gap, but is less robust than the above variables.

Religion matters; at least one religious variable is selected in each run. Protestantism, in particular, has strong and robust effects on the gender gap in mathematics. The variable is selected four times out of five and its coefficients are positive and highly significant: they range from 0.09 to 0.12 (at 1% significance levels). As the regressor is the share of Protestants on the population, the point estimate implies that when a country goes from being non Protestant to Protestant, the gender gap in mathematics narrows by 9 to 12 points. This result provides new evidence on the gender gap in mathematics and is consistent with the findings of Norton and Tomal (2009) and Becker and Woessmann (2008) regarding more generally religion and education.

Table 2

Muslim religion is selected in three out of five cases, with positive coefficients ranging from 0.07 to 0.9 (significance at 5%, 10%, and lower). The result differs from the finding of Norton Tomal (2009) on education but is consistent with that of Fryer and Levitt (2010), who focus specifically on the gaps in mathematics. While in the latter authors' view, the good relative performance of girls in Muslim countries is due to the separation of classes between genders, we think it may be affected by the higher average family background of girls relatively to that of boys, which has been discussed above. Individual background factors are controlled for at step 1 of the analysis, but they can still affect coefficients indirectly, for example through a higher average quality of schools or classes attended by girls relatively to boys.

The *Catholic* religion variable has a negative coefficient of -0.07 in Model I, at a significance level of 1%, showing that to a larger presence of Catholics in countries corresponds a more negative gender gap in mathematics. More precisely, when a country goes from being non Catholic to Catholic, the gender gap worsens by 7 points. This provides new evidence on the relation between Catholicism and girls' relative performance in mathematics, which is consistent with the more general finding of Norton and Tomal (2009) on Catholic religion and gender gaps in overall education. Our results show that girls in Catholic countries lag behind boys in mathematics more than their peers in the other groups of countries. The *Catholic* variable, however, is less robust than the others concerning religion, once the expectations on future jobs are added to the pool, it stops to be selected by the BIC. This suggests that the - low - expectations on future jobs capture much of the correlation between Catholic religion and gender gap: in Table Ax the correlation between *stem job expectations: girls/boys* and *Catholic* religion is negative, with a value of - 43.

A communist past has a positive, strong and very robust effect on gender gaps. To our knowledge this is an original result. The dummy *communist background* is always selected by BIC, with coefficients showing that the gender gap of a country going from not having to having a communist background improves from 7.27 to 13.41 points, at significance levels of 1%. This suggests that the main social and institutional features of the past communist regimes still affect, positively, the gender gap in mathematics. As said, the ban of religiosity together with the declared goal of gender parity at school and in labour markets may have substantially influenced people's mentality, as well as social rules and educational patterns, favouring the convergence of the school performance of girls to that of boys. Given the cross section character of our data, we are not able to rule out that other characteristics of these economies contribute to explain the variable's significant and high coefficients.

A third robust result emerging from this study is that the expected economic opportunities of studying math matter significantly. More precisely, gender gaps are narrower as girls, relatively to boys, assign a higher probability of working in the future in the *stem* sectors of the economy, where mathematical knowledge turns out to be useful. The variable *stem job expectations: girls-boys*, is always selected when included in the pool. As it is a difference between shares of girls and of boys, its coefficients imply that to a 0.18 standard deviation of the regressor (from Table x) corresponds a narrowing of the gap going from 2.96 points, in Model II, to 3.45 points, in Model IV, respectively (significance levels are always at 1%).

Other, less robust, results re as follows. The average attitudes of students concerning the importance of math, *math important: all students*, has a coefficient of 16.49, at the 5% significance level in Model I. In other terms, a 0.10 standard deviation (from Tablex) of this share corresponds a 1.65 improvement in the gender gap. [check] By using the data provided by the World Values Survey, we have analyzed the correlation of this variable with a proxy of the opinions of people in x countries regarding the significance of advances in the scientific and technical knowledge for the human well-being. We find this relation to have a positive and significant coefficient, suggesting that the attitudes of students, and of girls, regarding the study of math is related their countries' beliefs on the importance of scientific knowledge (Table Ax). The attitude of students regarding the study of math is not selected any more once job expectations are included into the pool, also in this case suggesting that expectations on future jobs explain more than attitudes and opinions about the study of mathematics.[8]

[8] The responses to the World Values Survey question on this issue, our variable *wws* in Table Ax, show a substantial heterogeneity between countries (46 of the WWS countries overlap with those of PISA 2006). Regressing the attitudes of students, *math important*, on the *wws*, controlling for countries' levels of development and religion, we get positive and significant coefficients: a higher share of students think that math is important in countries where the general opinion about scientific and technical knowledge is more positive. Moreover, in these countries, girls' attitudes with respect to math are also more similar to those of boys' (Table Ax).

Differently from expected, the coefficients of *female prof. tech. workers* are negative in Model IV and V. However, if the variable *communist background* is not included into the pool, the former coefficient becomes positive and significant. It shows that the effect of the presence of female workers in the strategic sectors of the economy is captured the more robust variable, *communist background*. This is consistent with both the high average rate of professional and technical workers in ex-communist countries (Table x) and by the correlation between the two variables, of 0.63, in Table Ax.

Finally, the Gender Gap Index variable, *ggi*, utilized in Guiso et al (2008) as the main indicator of the empowerment of women in society is not selected, suggesting that that the ggi, based on length of education, life expectancy, gender parity in the economy and in politics, as measured by the World Economic Forum, is not robustly related to the gender gap in mathematics. It is related to development, but, as we have already seen, the *ggi* is high in Catholic countries, where negative gender gaps are wide, and is lower in ex-communist or Muslim countries, where gender gaps are substantially narrower. Even controlling within sub-samples, we find that there is no correlation between the *ggi* and gender gaps, except for the Protestant group of countries.

The countries' level of development as represented by the level of per capita income and the income growth rates, when selected, have the expected signs. The positive coefficients of the *ln average test score*s variable in Models II and III shows what seems to be a 'convergence' of girls' toward boys' performances in math as the average level of scores increase.

Having a cross-country dataset we cannot perform tests of causality. Two variables, religion and communist background, can reasonably be taught to be exogenous to the gender gap in mathematics. Regarding the former, we have been able to utilize data from… on the predetermined variable in year 1900 … . to run 2SLS, using religions in our 57 countries in year 1900 as instruments. We have not detected endogeneity (results are available from the authors upon request). A problem of circularity, or a lock-in mechanism, rather a causal link, might instead be at work between education and the labour market: more optimistic expectations on future jobs in the *stem* sectors of the economy may induce girls to invest more in the study of math, increasing the supply of female technical and scientific workers in the labour force and their presence in stem occupations, which, in turn, cab support girls' optimistic expectations. If at work, this mechanism seems to indicate that, despite education comes first, decisive improvements in gender parity at school, and particularly in mathematics, are effective only when accompanied by decisive improvements in gender parity in the economy.

V. Conclusions

PISA and other sources of cross-country data show that girls tend to perform better than boys at school, except in mathematics. Girls tend to repeat grades less than boys and to get higher scores in reading, and yet they generally lag behind in math.

Some reasons for this negative performance have been examined in this paper. We have found that culture and institutions strongly matter and that girls behave rationally: they study more math and get higher scores when they expect to use this knowledge in their future working life.

Given previous findings of the literature, a relation between culture and education was expected. What this paper shows is that, among the proxies of culture we consider, the one strongly correlated to the gender gaps is religion. More specifically, while Protestantism affects positively the relative performance of girls, the effect of Catholicism is negative. Girls in Catholic countries lag behind boys in math more than in Protestant, Muslim and ex-communist countries.

What remains of the past economic institutions, social rules and schooling of communism, with the more recent ones of the 'transition economies' of our sample, exert a robust a strongly positive influence on the relative performance of girls in math. To our knowledge, this is an original finding, which can be further analyzed in future research.

Finally, expectations of future jobs are strongly correlated with relative scores. Girls appear to rationally choose an education that will be useful in their adult life. Where they know that their chances, relatively to males, of working in the sectors of the economy related to science, technology, engineering and mathematics are small, they study relatively less hours of math, and get relatively lower scores.

Effective policies for closing the gender gap in mathematics must therefore concern both education and the economy. Appropriate school programs and policies aiming at a greater gender parity in the study of scientific and technical subjects should be implemented together with changes in the practices and rules of labour markets, in turn aiming at a higher gender parity in the better paid occupations.

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Table 1. Summary statistics of some variables of interest

Variable	ALL	Catholic	Protestant	Muslim	Communist background
unconditional gap	-9.40	-12.86	-8.6	-2.45	-5.95
	(7.86)	*(6.59)*	*(5.9)*	*(11.34)*	*(5.31)*
gap	-17.67	-21.90	-15.02	-12.46	-13.07
	(7.48)	*(4.71)*	*(7.7)*	*(11.53)*	*(4.14)*
gdp_growth	5.6	4.9	3.2	9.0	7.9
	(3.64)	*(2.57)*	*(0.97)*	*(6.48)*	*(4.76)*
ln math important: all students	4.42	4.42	4.47	4.41	4.41
	(0.10)	*(0.07)*	*(0.06)*	*(0.09)*	*(0.09)*
math important: girls-boys	-1.57	-2.81	-1.67	2.73	0.12
	(6.22)	*(5.38)*	*(4.33)*	*(6.51)*	*(6.19)*
hours of math: girls-boys	-0.34	-0.91	-0.59	0.98	-0.19
	(2.46)	*(2.34)*	*(2.28)*	*(2.35)*	*(2.1)*
average test scores	469	471	508	381	461
	(59.32)	*(49.97)*	*(21.36)*	*(57.95)*	*(53.81)*
STEM job expect.: all students	13.16	14.25	11.64	12.00	13.25
	(3.37)	*(3.28)*	*(2.65)*	*(5.03)*	*(3.18)*
STEM job expect.: girls /boys	0.42	0.34	0.38	0.55	0.49
	(0.18)	*(0.08)*	*(0.11)*	*(0.14)*	*(0.22)*
labor force p. rate: female/male	0.73	0.72	0.84	0.53	0.78
	(0.13)	*(0.09)*	*(0.04)*	*(0.22)*	*(0.05)*
female prof. tech. workers	52.33	52.45	53.22	44.20	59.63
	(7.96)	*(5.97)*	*(3.23)*	*(15.02)*	*(5.63)*
ggi	0.691	0.687	0.760	0.631	0.679
	(0.05)	*(0.03)*	*(0.04)*	*(0.03)*	*(0.03)*
econ-ggi	0.654	0.640	0.736	0.528	0.686
	(0.08)	*(0.07)*	*(0.02)*	*(0.09)*	*(0.04)*

Note: mean values (standard deviations)

Table 2. Dependent variable: gender gap in mathematics. *BIC selection and OLS*

Variables	Model I	Model II	Model III	Model IV	Model V
ln pcgdp	4.07 **			3.84 **	2.29
	(2.63)			*(2.62)*	*(1.54)*
gdp growth				0.61 **	
				(2.31)	
religion: catholic	-0.07 ***				
	(3.82)				
religion: protestant		0.09 ***	0.09 ***	0.12 ***	0.12 ***
		(3.20)	*(2.72)*	*(4.06)*	*(3.8)*
religion: muslim	0.08	0.09 **	0.07 *		
	(1.65)	(2.28)	*(1.88)*		
communist background	8.63 ***	7.51 ***	7.27 ***	12.29 ***	13.41 ***
	(5.23)	*(4.57)*	*(4.52)*	*(6.09)*	*(5.77)*
math important: all students	16.49 **				
	(2.29)				
hours of math: girls - boys	0.70 *			0.90 **	0.81 **
	(1.69)			*(2.53)*	*(2.29)*
ln average test score		25.84 ***	22.67 ***		
		(3.5)	*(3.68)*		
job expectations: all students		0.42 *			
		(1.93)			
job expectations: girls/boys		16.44 ***	17.23 ***	19.15 ***	16.58 **
		(2.98)	*(3.02)*	*(3.31)*	*(2.56)*
female prof. tech. workers				-0.51 ***	-0.47 ***
				(-4.18)	*(-3.83)*
(Intercept)	-131.81 ***	-194.05 ***	-169.02 ***	-45.80 ***	-28.65 *
	(-3.87)	*(-4.12)*	*(-4.38)*	*(-3.27)*	*(-1.68)*
Adjusted R^2	0.444	0.515	0.488	0.580	0.525
N. observations	57	56	56	50	50

*Note: *** 1%, ** 5%, *10% significance level (t values) based on White's heteroskedasticity robust standard errors*
Pool 1: ln av. test scores, math important: all, math important: girls - boys, hours of math: girls - boys, Catholic, Protestant, Muslim, communist backg., pcgdp, gdp growth

Pool 2: pool 1 + stem job expectations: all, stem job expectations: girls - boys. Pool 3: pool 2 + labor force participation rate

Pool 4: pool 3 + female professional technical workers. Pool 5: pool 4 + ggi.

Appendix