Open Society Foundations - Armenia

Equity in Education in Armenia: Evidence from TIMSS 2003-2015

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Daniel Caro and Jia He

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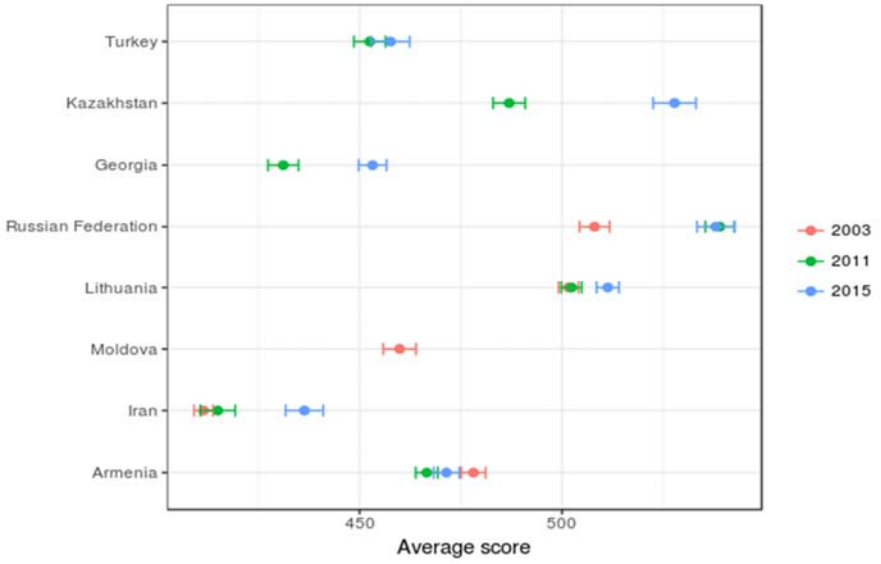
Introduction

Education is the great socioeconomic equaliser; quality and equity in education are important pillars to realize the goals to end poverty and bring out shared prosperity (Bowles, Gintis, & Osborne 2005; Goldthorpe, 2013). Ensuring all learners to have an equal opportunity to quality education is still a challenge in many countries, Armenia included (e.g., Gorard & Smith, 2004; van Damme & Bellens, 2017).

Despite that the Armenian national laws provide a solid legal foundation for the right and access to education, actual implementations and proper mechanisms for the effective fulfillment of quality and equity in education may still be lacking if guided by recent national and international evidence (Dye, 2003; OSF, 2017).

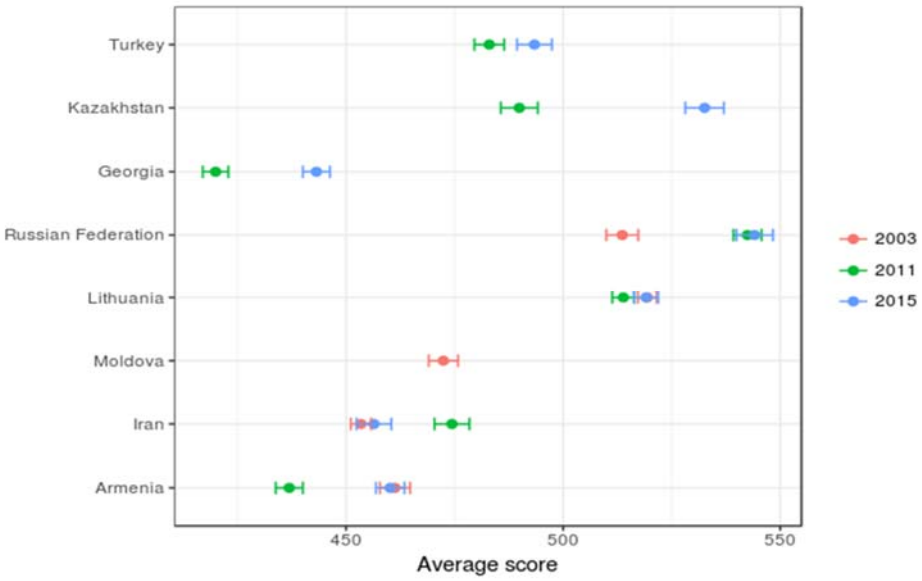
In terms of quality of education, student achievement outcomes in international tests point to relatively poor quality and effectiveness of the education system compared to other countries in the region and raise concerns about the sustainability of educational outcomes and economic development. Figure 1 and 2 display performance in mathematics and science for Grade 8 students in Armenia and selected benchmark countries participating in the Trends in International Mathematics and Science Study (TIMSS; Mullis, Martin, Gonzalez & Chrostowski, 2004; Mullis, Martin, Foy & Arora, 2012). Armenia performed under the international average (set at 500 points), and not as well as neighbouring countries such as Kazakhstan, Lithuania and Russian Federation in mathematics and science. Further, Armenia's achievement in both subjects has remained relatively stagnant or even deteriorated between 2003 and 2015, whereas Kazakhstan and Russian Federation saw improvements during this same period. Overall, 21% of Grade 8 students in Armenia performed below the lowest proficiency level established by TIMSS in 2015, whereas only 5% and 2% did not reach this level in the Russian Federation and Kazakhstan, respectively. This suggests stagnation of educational quality in Armenia, and begs to identify causes and remedies to the situation.

Figure 1. Average mathematics performance in TIMSS



Note. Dots indicate average values and bars standard errors. These values are presented in Table A2 in Appendix A.

Figure 2. Average science performance in TIMSS



Note. Dots indicate average values and bars standard errors. These values are presented in Table A2 in Appendix A.

In terms of equity, results from TIMSS 2011 show that home resources are related to student achievement across countries and in Armenia as well (e.g., Mullis et al, 2012), thereby indicating that students from different socioeconomic backgrounds do not have the same opportunity to succeed (Parcel & Dufur, 2001). More recent national data from a sociological survey of parents in Armenia revealed that, compared with students from better-off families, fewer students from impoverished families achieved excellence grades, and sharp achievement differences were highlighted between urban and rural areas (OSF, 2017). We know from research that inequities during the school period have long-lasting effects on educational and economic attainment. Particularly, students from socio-economically disadvantaged backgrounds not only perform worse in schools than students from affluent families, but are also more likely to attain lower education levels and earn less in the labour market as adults (Kerckhoff, Raudenbush, & Glennie 2001; Rumberger, 2010). The importance of research and policies for reducing inequities in school is therefore emphasised.

In recent years, various policies and programs have been implemented for general education aiming to improve educational quality in Armenia. However, lack of access to quality general education for different groups of students increasingly becomes a precarious issue. For instance, there is a governmental plan to implement the National Education Excellence Program and to implement the Ararat Baccalaureate in high schools. These national policies and programs may target “ensuring the effectiveness and efficiency of the system and equal access to education according to the aspirations and abilities of every citizen” (Ministry of Education and Science, 2015, p. 9). They are, however, mainly only accessible to students located in urban areas, implying a strategy of elitist

education within the system of general education, which may exacerbate the existing social polarization and poverty (OSF, 2017).

Aims

The aim of this report is to answer key policy research questions related to equity in education in Armenia with data from TIMSS 2003, 2011, and 2015[1]. Conceptually, equity is approached from an *equality of opportunity* perspective.[2] The underlying normative assumption is that inequities related to socio-economic status (SES) are unfair and that they can be measured through the relationship between family SES and student achievement. The analytic approach draws on previous research for developing a measure of SES in Armenia (Caro & Cortés, 2012) and examining the research questions relating to equity in education (Caro & Lenkeit, 2012). Equity results in Armenia are compared over time from 2003 to 2015 as well as cross-sectionally with benchmark education systems[3]: Georgia, Iran, Kazakhstan, Lithuania, Moldova, the Russian Federation, and Turkey.

The following research questions are addressed.

1. What is the relationship between SES and academic achievement? How has it changed over time?

2. Does the school SES play a role in student achievement above and beyond the role of family SES? Or, in other words, are low SES students in *double jeopardy* for coming from low SES backgrounds and attending low SES schools?

3. What is the student achievement gap between urban and rural areas? How has it changed over time?

4. Is the urban-rural gap explained by the availability of school resources for student instruction?

5. Is the urban-rural gap explained by the SES composition of the school student intake?

The report is organised as follows. The next section presents the methodology for measuring SES in Armenia. Drawing on the socio-economic segregation structure in Armenia, an SES score is calculated for each student in Armenia and across benchmark education systems in 2003, 2011, and 2015. Next, following Caro and Lenkeit (2012), the underlying hypothesis, statistical model, and

[1] Armenia also participated in TIMSS 2007, but results were exceptionally high and are not considered valid (Khachatryan, Petrosyan, Terzyan, 2013).

[2] Equity in education can be conceptualised from different perspectives with different normative and measurement implications (Strietholt & Borgna, 2016). In addition to the equality of opportunity perspective, an egalitarian perspective or capability approach could be adopted. The *egalitarian perspective* assumes that all inequalities in educational outcomes are unfair and equity is thus measured through simple dispersion indicators (e.g., standard deviation of academic achievement). From a *capability approach*, a minimum level of educational attainment is expected and inequalities can therefore be measure through, for example, the percentage of students reaching a basic literacy level (e.g., students performing above proficiency level 2 in the Programme for International Student Assessment [PISA] test).

[3] The list of participating countries in TIMSS can be found here: 2003, 2011, and 2015. Note that because Azerbaijan did not administer TIMSS in Grade 8, comparisons are not possible.

results are presented for each research question. Finally, the last section discusses main findings and related policy implications.

The characteristics of the data, including sample sizes, variables, descriptive statistics, and missing data, are presented in Appendix A. Analyses take into account the multilevel structure of the data (i.e., students nested in schools) and the rotated test design (i.e., plausible student achievement values) in TIMSS using the R package 'intsvy' (Caro & Biecek, 2017).

Measuring SES in Armenia

This section presents the methodology for calculating a measure of SES in Armenia that is comparable across benchmark countries and over time from 2003 to 2015.

SES definition and operationalisation

SES is typically defined as the relative position of an individual or family within a hierarchical social structure, based on their access to, or control over wealth, prestige, and power (Mueller & Parcel, 1981). SES indexes are traditionally operationalised through measures characterizing parental educational levels, parental occupational prestige, and home possessions (Buchmann, 2002; Caro & Cortés, 2012). There is, however, no consensus on how to measure SES in a standard manner, because various definitions and operationalisation procedures coexist (Caro, Sandoval-Hernandez, & Lüdtke, 2014). For example, some studies refer to concepts of cultural capital and economic capital instead of SES, and other studies use the number of books at home as a single SES indicator due to limited data. Clearly, data availability somewhat determines SES operationalisation procedures. This study builds on the available data in TIMSS to capture different aspects of SES and calculate a composite score of SES in Armenia and benchmark countries.

SES constituent items

The derived SES measure relies on available data in TIMSS relating to traditional SES constituent items (i.e., parental education, parental occupations, and home possessions) that were measured consistently in 2003, 2011, and 2015 in order to produce a comparable SES measure over time. Data on parental education, the availability of a desk and computer at home, and the number of books at home were collected consistently across cycles. Data on parental occupation were not collected in TIMSS. As a result, the following items were considered for measuring SES:

Parental education (PARED): Highest level of education attained by either parent (1: some primary, lower secondary or no school; 2: lower secondary; 3: upper secondary; 4: post-secondary but not university; 5: university or higher).

Number of books (BOOKS): Number of books at home (1: none or very few [0-10 books]; 2: enough to fill one shelf [11-25 books]; 3: enough to fill one bookcase [26-100 books]; 4: enough to fill two bookcases [101-200 books]; 5: enough to fill three or more bookcases [more than 200 books]).

Home possessions (HOME): Possession of computer and/or desk at home (0%: no computer or desk; 50%: computer or desk at home; 100%: computer and desk at home).

SES scaling methodology

Following standard operationalisation procedures (e.g., Caro & Cortés, 2012), SES constituent items (i.e., parental education, number of books, and home possessions) were summarised into a single SES scale by means of principal component analysis (PCA). PCA was applied on SES standardised items by country and TIMSS cycle. Derived factor loadings are presented in Table 1.

Table 1. SES factor loadings

	2003			2011			2015		
	PARED	BOOKS	HOMEPOS	PARED	BOOKS	HOMEPOS	PARED	BOOKS	HOMEPOS
Armenia	0.60	0.62	0.51	0.59	0.59	0.55	0.63	0.62	0.47
Georgia				0.58	0.61	0.54	0.63	0.64	0.43
Iran	0.59	0.58	0.56	0.60	0.55	0.58	0.62	0.58	0.53
Kazakhstan				0.56	0.59	0.58	0.56	0.62	0.54
Moldova	0.60	0.63	0.49	0.56	0.59	0.58			
Lithuania	0.60	0.58	0.54	0.67	0.65	0.37	0.68	0.68	0.27
Russian Federation	0.59	0.59	0.55	0.62	0.60	0.51	0.68	0.67	0.31
Turkey				0.58	0.57	0.58	0.61	0.60	0.52

Note: Factor loadings were anchored to values in Armenia 2015 (highlighted).

The factor loadings did not vary largely across education systems and over time. Factor loadings (i.e., weights in the SES measure) for parental education and books were consistently stronger than for home possessions. This result is in agreement with previous research showing that SES indicators reflecting economic capital and cultural capital (e.g., parental education and books) are most important for social stratification, that is, for determining SES levels. The two home possession items included in TIMSS 2003, 2011, and 2015 (i.e., desk and computer at home) serve as a weak indicator of home possessions. However, the moderate weight of home possessions for SES is meaningful. Research shows that the weight of home possessions for social stratification decreases with the country's level of economic development (Caro & Cortés, 2012).

Factor loadings were anchored to values in Armenia 2015 in order to develop a comparable SES measure over time and across countries. To the extent that factor loadings do not vary largely across education systems and over time, the assumption that factor loadings are fixed to the values in Armenia 2015 is plausible. A single SES score was calculated for each student *i*, in education system *j*, and TIMSS cycle *t*:

$$SES_{ijt} = \alpha_1 PARED_{ijt} + \alpha_2 HOMEPOS_{ijt} + \alpha_3 BOOKS_{ijt} \quad \ldots(1)$$

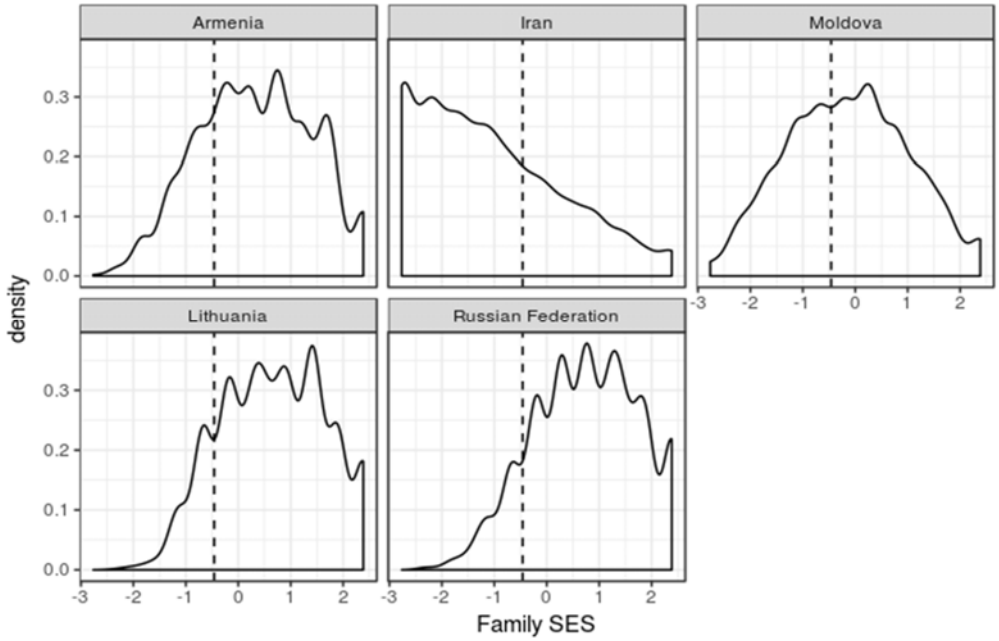
Factor loadings, α_s, are highlighted in Table 1. The resulting SES score was centred at the population mean SES score of students in Armenia in 2015.

SES and poverty

Latest figures indicate that around 30% of the Armenian population lives below the poverty line (see, for example, World Bank and Central Intelligence Agency). From those in poverty, approximately 19% are poor, 8% are very poor, and 2% extremely poor (National Statistical Service of the Republic of Armenia, 2016). Poverty rates are relatively similar in urban and rural areas. Armenia has managed to reduce poverty from 54% in 1998, but the poverty rate has remained stagnant around 30% since the global economic crisis in 2008.

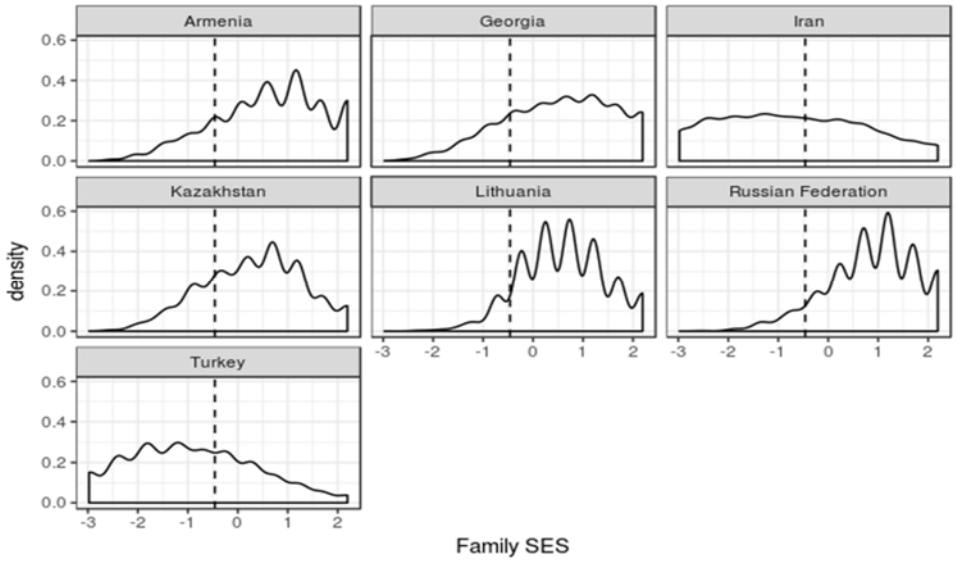
SES and poverty measures are not the same, but they can be related by looking at the distribution of SES scores. Figure 3, 4, and 5 present the SES distribution across countries in 2003, 2011, and 2015, respectively.

Figure 3. SES distribution in 2003



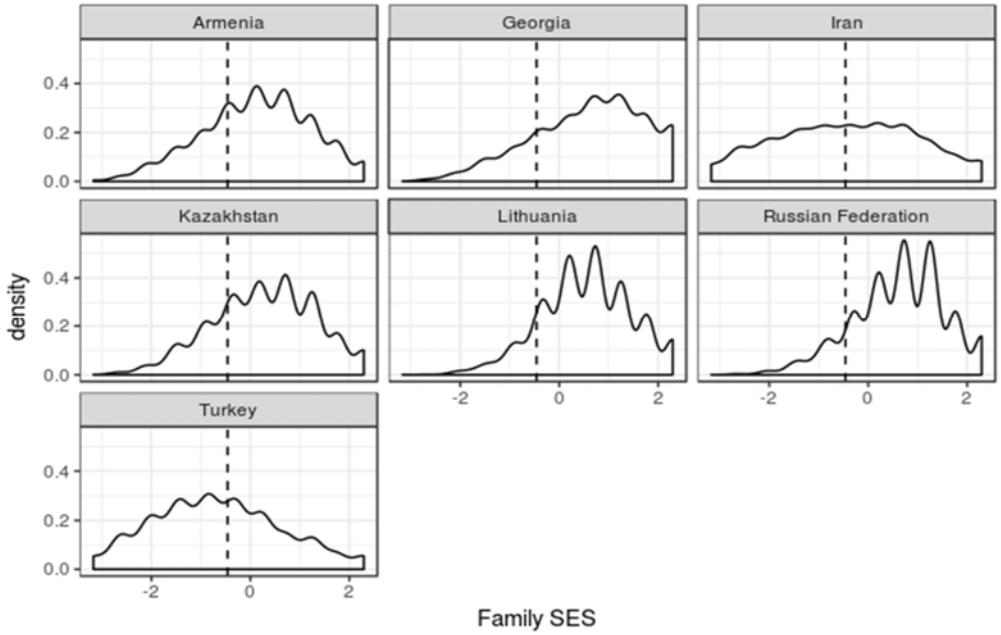
Note. The vertical dashed line at the SES score of -0.46 is equivalent to the 30th SES percentile in Armenia in 2015.

Figure 4. SES distribution in 2011



Note. The vertical dashed line at the SES score of -0.46 is equivalent to the 30th SES percentile in Armenia in 2015.

Figure 5. SES distribution in 2015



Note. The vertical dashed line at the SES score of -0.46 is equivalent to the 30th SES percentile in Armenia in 2015.

A vertical line was drawn at the SES score of -0.46, the 30th percentile in the SES measure in Armenia in 2015. Those in poverty, that is 30% of the student population, had an SES score below -0.46. The value of -0.46 represents the SES poverty line. The great majority of students in the Russian Federation and Lithuania scored above the SES poverty line in Armenia. For this group of students, differences in SES were not necessarily caused by poverty. That is, low SES students were

not living in poverty according to Armenian standards. In Armenia, however, when we compare differences in student achievement related to SES in the following sections, we need to bear in mind that the SES gap might reflect differences between those living in poverty and those not.

As can be seen the scores on the SES scale were not fully continuous. The reason is that SES constituent items contained a reduced number of ordered options: five ordered categories for parental education and books, and three ordered categories for home possessions. Limited variability in SES was a limitation due to data availability in TIMSS. With more SES items measured consistently over time, greater variability in SES would be captured, that is, an SES measure that distinguishes more finely among students in terms of their SES could be produced.

Analyzing equity in education

The association between SES and student achievement

The first and most basic research question concerns the overall association between SES and academic achievement, and how it changed from 2003 to 2015.

Hypothesis

Extensive research shows that SES is positively related to student performance; that is, students from low SES backgrounds tend to perform worse in school compared to students from high SES families (Sirin, 2005; White, 1982). Accordingly, a positive relationship between SES and student achievement is expected in Armenia.

Statistical model

The gradual relationship between SES and student achievement can be described in socio-economic gradient lines (Caro & Lenkeit, 2012; Willms, 2006). A socio-economic gradient is estimated with the following regression model.

$$y_{ij} = \beta_0 + \beta_i SES_{ij} + e_{ij} \quad \text{...(2)}$$

For each student *i* in school *j*, *y* represents the corresponding mathematics/science score, *SES* the score in the SES scale, and *e* the error term. A separate model was estimated for each country. Parameters β_0 and β_1 contained critical information about the performance of education systems: effectiveness and equity in performance, respectively.

Estimates of the intercept β_0 reflect average achievement when SES is zero. Since SES was centred at the mean SES in Armenia in 2015, zero in the SES scale represented the average SES in Armenia. Countries may perform differently due to varying SES levels of students. Raw estimates of performance (e.g., global education rankings) did not take into account that education systems served student populations from potentially very different SES contexts (e.g., Armenia vs Norway). Estimates of β_0 allowed us to compare performance between countries independently of differences in SES levels. These estimates provided a measure of performance that was adjusted by SES levels. With that, they provided a fairer picture of country comparisons in student performance. Such

measures of performance are referred in educational research to as *effectiveness in performance* (Creemers & Kyriakides, 2008).

Estimates of the slope β_1 indicate the association between SES and student achievement. Particularly, these estimates measured changes in achievement scores for a unit change in SES in each country. Positive values indicated that higher SES students perform better than lower SES students. Negative values indicated that lower SES students perform better than higher SES students. Parameter β_1 was our measure of *equity in performance* that adheres to the equality of opportunity perspective. According to the literature, positive and statistically significant estimates of β_1 are expected.

Results

Table 2 reports SES coefficients (β_1) arising from regressions of mathematics and science achievement on SES.

Table 2. Regression of mathematics and science achievement on SES (unstandardized coefficients)

	Mathematics			Science		
Education system	2003	2011	2015	2003	2011	2015
Armenia	**15.89**	**25.10**	**20.25**	**15.16**	**23.02**	**20.88**
Georgia		**34.53**	**26.59**		**27.50**	**26.63**
Iran	**17.88**	**29.96**	**27.09**	**14.60**	**26.99**	**26.38**
Kazakhstan		**21.70**	**13.19**		**25.07**	**14.34**
Lithuania	**33.94**	**40.09**	**32.23**	**24.30**	**37.94**	**33.07**
Moldova	**16.61**			**15.99**		
Russian Federation	**25.80**	**26.65**	**18.62**	**24.34**	**27.64**	**20.61**
Turkey		**40.84**	**35.77**		**34.15**	**31.15**

Note. Coefficients in bold are statistically significant ($p < 0.05$)

Consistent with our hypothesis, coefficients were positive and statistically significant across countries and over time.

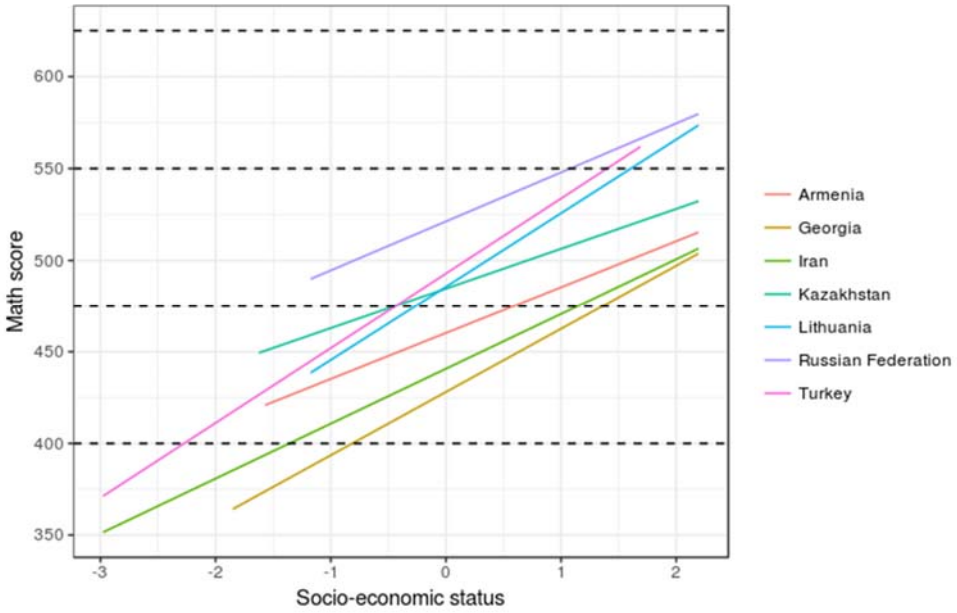
Figure 6 and 7 display socio-economic gradient lines in mathematics in 2011 and 2015. Figures 8 and 9 display socioeconomic gradients in science in 2011 and 2015 (see Figures B1 and B2 in Appendix B for socio-economic gradients with TIMSS 2003). The x-axis and y-axis represent scores in SES and student achievement, respectively. Dashed lines indicate international proficiency benchmarks established by TIMSS: low international benchmark (400 points), intermediate international benchmark (475 points), high international benchmark (550 points), and advanced international benchmark (625 points).

Slopes of gradient lines illustrate equity in performance and intercepts of regression lines illustrate effectiveness in performance. Steepest gradient slopes were found in Lithuania (32 and 33 score

points) and Turkey (36 and 31 score points) for mathematics and science in 2015, respectively (see Table 2).

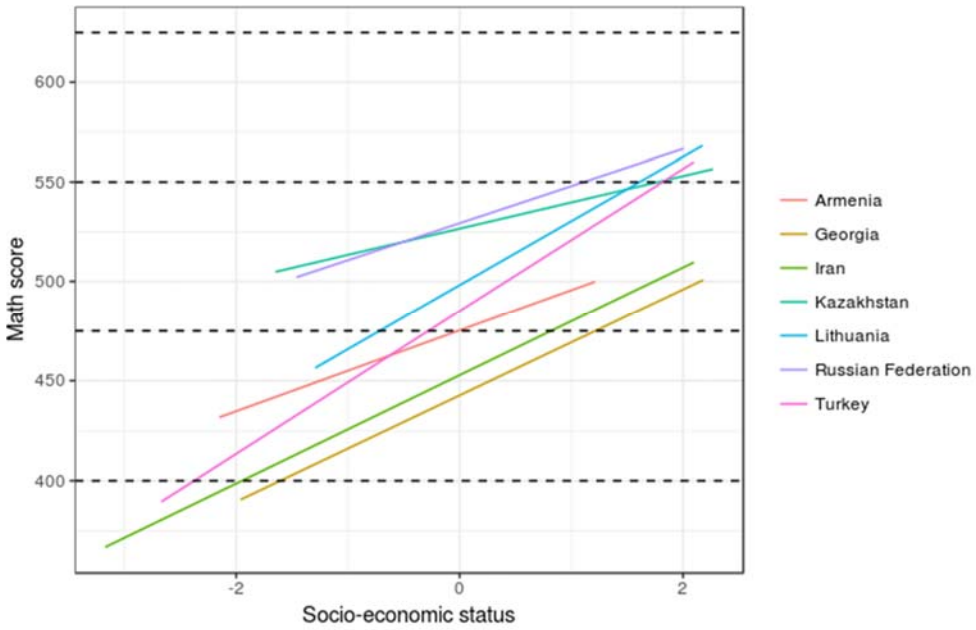
Effectiveness was evaluated by drawing a vertical line at zero in the x-axis, that is, the average SES in Armenia in 2015. At this SES level, students in Armenia, Georgia, and Iran performed worse than students in other countries, and students in the Russian Federation, Turkey and Lithuania performed better than the rest. That is, education systems in Armenia, Georgia, and Iran were relatively ineffective in serving students with low SES backgrounds. The problem was aggravated by low proficiency levels reached by students in these countries. Comparatively, students with equivalent SES levels performed better in other countries. Effectiveness in performance in the Russian Federation, Kazakhstan, and Turkey stood out. However, as noted earlier, inequities were relatively large in Turkey.

Figure 6. TIMSS 2011: Socio-economic gradients in mathematics



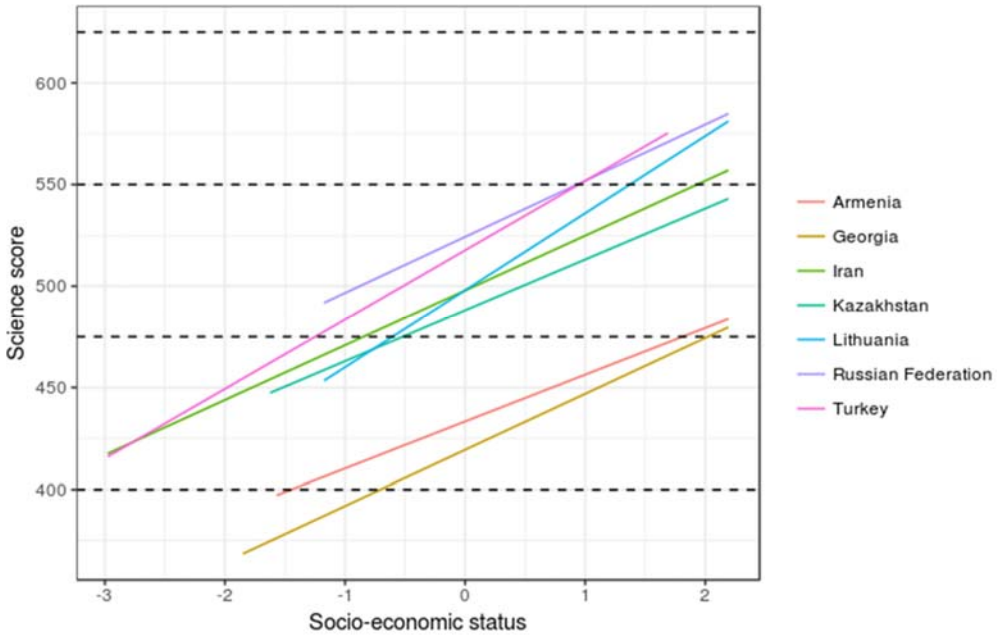
Note. Dashed lines indicate proficiency levels established by TIMSS: low international benchmark (400 points), intermediate international benchmark (475 points), high international benchmark (550 points), and advanced international benchmark (625 points).

Figure 7. TIMSS 2015: Socio-economic gradients in mathematics



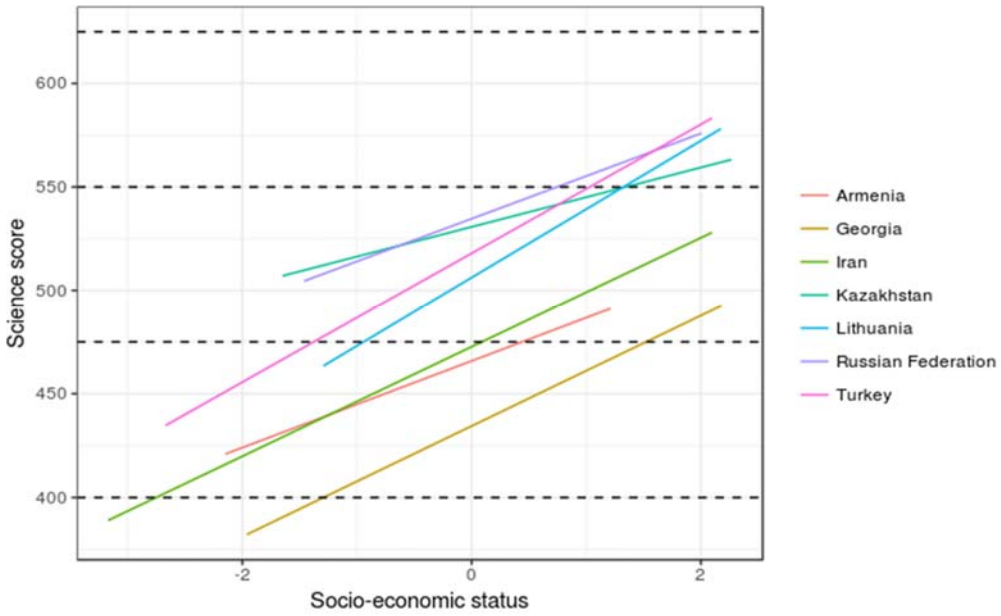
Note. Dashed lines indicate proficiency levels established by TIMSS: low international benchmark (400 points), intermediate international benchmark (475 points), high international benchmark (550 points), and advanced international benchmark (625 points).

Figure 8. TIMSS 2011: Socio-economic gradients in science



Note. Dashed lines indicate proficiency levels established by TIMSS: low international benchmark (400 points), intermediate international benchmark (475 points), high international benchmark (550 points), and advanced international benchmark (625 points).

Figure 9. TIMSS 2015: Socio-economic gradients in science

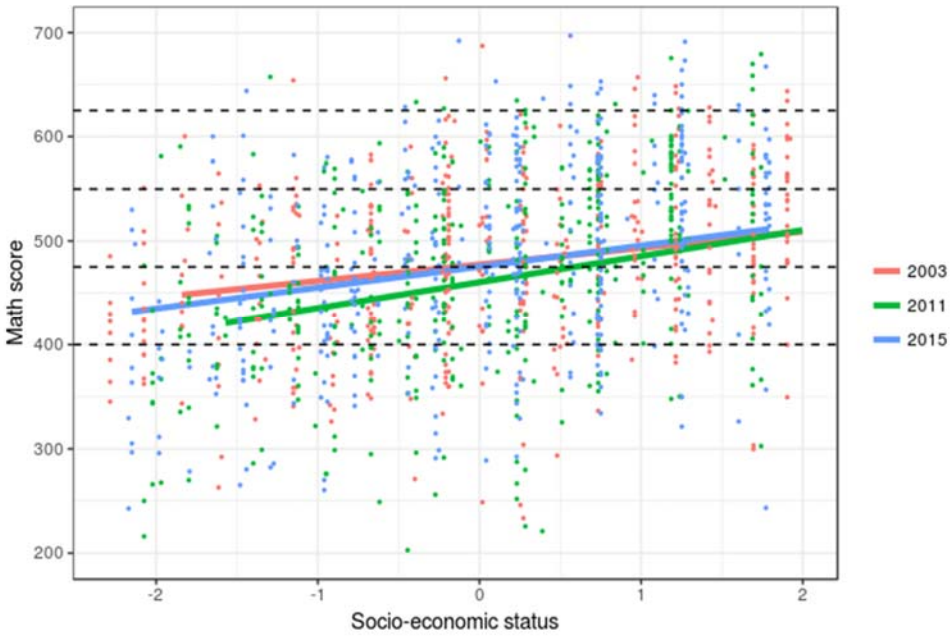


Note. Dashed lines indicate proficiency levels established by TIMSS: low international benchmark (400 points), intermediate international benchmark (475 points), high international benchmark (550 points), and advanced international benchmark (625 points).

Figure 10 and 11 depict socio-economic gradients for mathematics and science in Armenia. In addition to gradient lines, dots represent actual achievement and SES scores for a random sample of students in each year and dashed lines indicate international proficiency benchmarks.

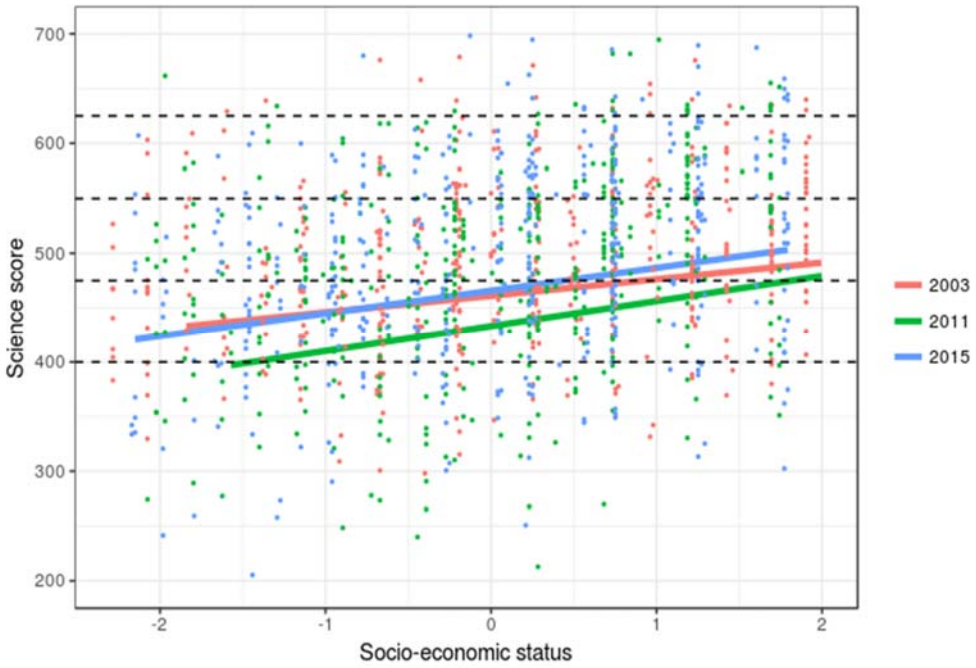
Inequities in Armenia measured by the gradient slope increased from 2003 to 2015 for both mathematics (16 vs 20 score points) and science performance (15 to 21 score points) (see also Table 2). That is, the SES gap in amounted to around 20% of a standard deviation in student achievement.

Figure 10. Socio-economic gradients for mathematics in Armenia



Note. Dots indicate observed data points for a random sample of 500 students in 2003, 2011, and 2015. Dashed lines indicate proficiency levels established by TIMSS: low international benchmark (400 points), intermediate international benchmark (475 points), high international benchmark (550 points), and advanced international benchmark (625 points).

Figure 11. Socio-economic gradients for science achievement in Armenia



Note. Dots indicate observed data points for a random sample of 500 students in 2003, 2011, and 2015. Dashed lines indicate proficiency levels established by TIMSS: low international benchmark (400 points), intermediate international benchmark (475 points), high international benchmark (550 points), and advanced international benchmark (625 points).

The socio-economic gradient lines summarise the relationship between SES and student achievement. Additionally, observed data showed substantial variability in student performance unexplained by SES. For example, there were many low SES students performing lower than expected, and high SES students performing higher than expected by regression lines. Other family and school factors beyond SES might explain differences in performance for students with comparable SES levels. Observed data showed as well that many low SES students did not reach the lowest proficiency level established by TIMSS.

The decomposition of the SES gap relating to families and schools

The second research question concerns the role of schools and families in the SES gap.

Hypothesis

Research shows that the school SES composition, measured by the student average SES in a school, affects student outcomes beyond and above the effect of family SES. School SES composition effects capture the influence of the school learning environment on student outcomes. These effects typically reflect school segregation in education systems; for example, segregation between public

and private schools, between different schools tracks (e.g., academic and vocational), and schools in different regions (e.g., urban and rural areas; Dupriez, Dumay, & Vause, 2008).

School SES composition effects can be obtained from a regression of student achievement on student and school SES. The school SES coefficient captures the school SES composition effect. Results of meta-analysis show that this coefficient is positive (r = 0.32; van Ewijk & Sleegers, 2010). Substantively, SES composition effects capture the expected difference in student achievement between two students with equivalent family SES levels but who attend schools with different SES intake (Caro & Lenkeit, 2012; Willms, 2010). Positive estimates indicate that given two students with comparable levels of family SES, the one attending a more socially disadvantaged school is also more likely to perform worse in school. In the literature on social discrimination, this twofold disadvantage is usually referred to as *double jeopardy* (Willms 2006, 2010). Our hypothesis postulates that disadvantaged students coming from low families and attending low SES schools in Armenia are in *double jeopardy*.

Statistical model

School SES composition effects may be captured with two equivalent regression models.

$$y_{ij} = \beta_0 + \beta_1(SES_{ij} - \underline{SES_j}) + \beta_2\underline{SES_j} + e_{ij} \quad \text{...(3)}$$

$$y_{ij} = \beta_0 + \beta_1 SES_{ij} + \beta_2\underline{SES_j} + e_{ij} \quad \text{...(4)}$$

$\underline{SES}$ is the average student SES in each school j. In Equation 3 the student SES is centred around the school SES mean. Thus, $\beta_1$measures pure within school SES effects, $\beta_2$measures between school SES effects, and $\beta_2 - \beta_1$measures SES compositional effects. In Equation 4, $\beta_2$mesures SES compositional effects directly. That is, the association with school SES after controlling for the student SES. $\beta_2 - \beta_1$ in Equation 3 and $\beta_2$in Equation 4 are equivalent estimates of SES composition effects.

Results

Table 3 and 4 report estimates of β_1(student SES) and β_2(school SES composition) from Equation 4 for mathematics and science achievement, respectively.

Table 3. Regression of mathematics achievement on student and school SES

	2003		2011		2015	
Education system	Student SES	School SES	Student SES	School SES	Student SES	School SES
Armenia	**11.75**	**17.15**	**20.46**	**17.47**	**19.80**	1.93
Georgia			**27.67**	**17.97**	**21.41**	**18.04**
Iran	**5.09**	**30.28**	**11.61**	**37.36**	**9.06**	**40.70**

Kazakhstan			**13.26**	**23.50**	**7.78**	14.10
Lithuania	**25.50**	**30.12**	**29.50**	**39.43**	**22.8**	**34.10**
Moldova	**9.98**	**22.69**				
Russian Federation	**16.11**	**25.27**	**16.86**	**28.72**	**13.57**	18.52
Turkey			**27.22**	**29.51**	**18.33**	**37.88**

Note. Coefficients in bold are statistically significant ($p < 0.05$)

Table 4. Regression of science achievement on student and school SES

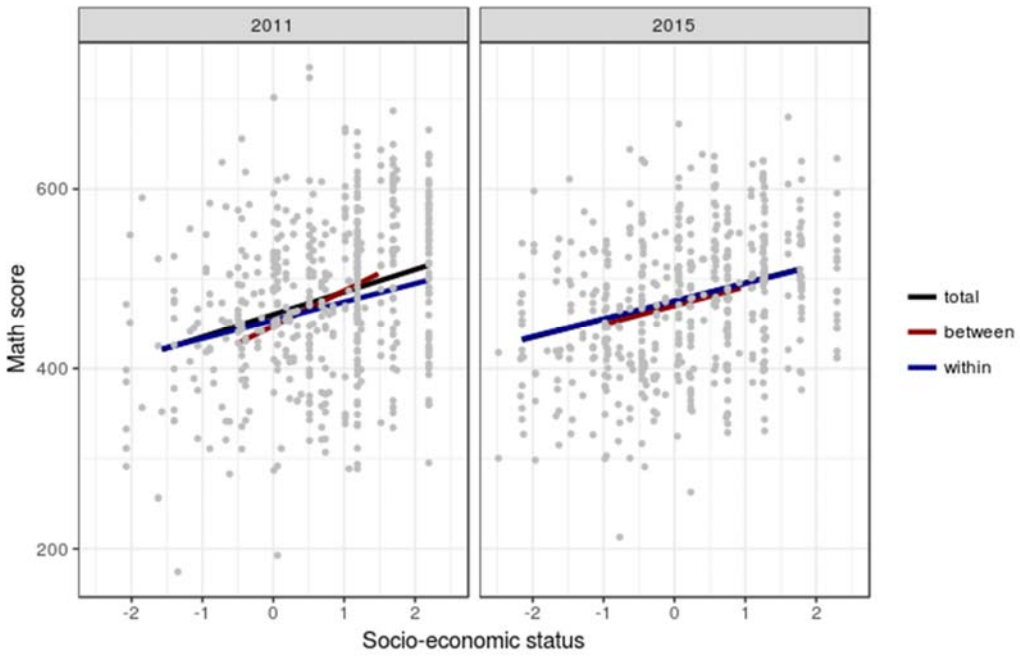
	2003		2011		2015	
	Student SES	School SES	Student SES	School SES	Student SES	School SES
Armenia	**10.99**	**17.29**	**20.87**	8.10	**21.39**	-2.15
Georgia			**25.02**	6.49	22.75	**13.51**
Iran	**4.54**	**23.82**	**11.33**	**31.88**	**10.61**	**35.58**
Kazakhstan			**12.53**	**34.89**	**7.03**	**19.07**
Lithuania	**18.96**	**19.07**	**28.68**	**34.49**	**24.24**	**31.93**
Moldova	**12.31**	**12.59**				
Russian Federation	**16.26**	**21.05**	**20.88**	**19.82**	**15.78**	**17.72**
Turkey			**23.03**	**24.09**	**16.58**	**31.65**

Note. Coefficients in bold are statistically significant ($p < 0.05$)

The student and school composition SES coefficients were positive and statistically significant across countries in 2003. Results consistently indicated that the school SES composition was associated with mathematics and science performance independently of the family SES. In other words, if we have two students with equivalent family SES levels, but one attends a school with a higher SES student-intake composition and another a lower SES school, the one attending the higher SES school would tend to perform better in science and math. Estimates were consistent with the *double jeopardy* hypothesis.

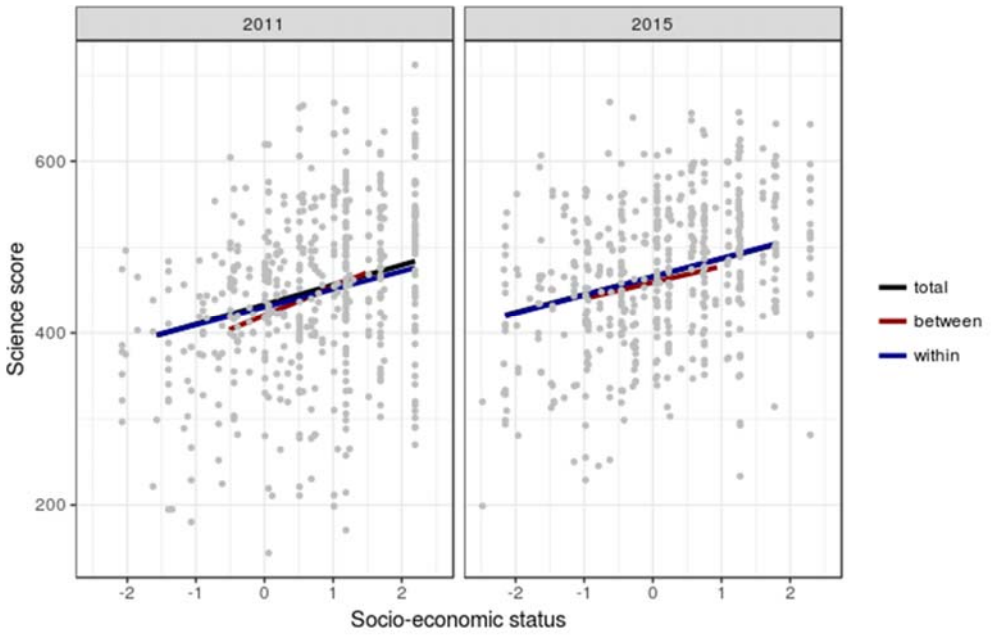
Figure 12 and 13 display for Armenia the overall (total) association with SES, the association within schools, and the association between schools for mathematics and science. The overall (total) association was derived from Equation 2. The association with SES within and between schools was derived from Equation 3. Differences in the steepness of school and student gradient lines reflected SES composition effects ($\beta_2 - \beta_1$ in Equation 3).

Figure 12. Socio-economic gradients between and within schools for match achievement in Armenia



Note. Dots indicate observed data points for a random sample of 500 students in 2011 and 2015.

Figure 13. Socio-economic gradients between and within schools for science achievement in Armenia



Note. Dots indicate observed data points for a random sample of 500 students in 2011 and 2015.

There were interesting variations in 2011 and 2015 compared with 2013. As reported earlier the SES gap increased from 2003 to 2011/2015. Further, the results of this hypothesis indicate that SES composition effects were positive and significant for maths and science in 2003, but not always in 2011 and 2015 (see Tables 3 and 4). The school SES slope was stepper than the student SES slope only for maths in 2011, but not for maths in 2015 and science in 2011 and 2015 (see Figures 12 and 13). That is, there was no strong evidence of school SES composition effects in 2011 and 2015. This is not to say that there was no association between the school SES and science performance.

The association was clearly positive as shown in Figure 12 and 13 (see between school effect). Rather, it indicated that the association between school SES and student performance was mainly explained by family SES differences within the school and not additionally by between school SES differences. In other words, SES segregation within the school appeared to be equally important as segregation between schools for explaining achievement gaps in 2011 and 2015.

The achievement gap between urban and rural schools

The third research question concerns the urban/rural gap in student performance.

Hypothesis

Research shows that students in rural schools perform worse than students in urban schools in developing contexts. Underperformance in rural areas often reflects high levels of centralisation and regional socio-economic disparities (Caro & Lenkeit, 2012, Geske, Grinfelds, & Zhang, 2006). International evidence shows that the urban-rural gap tends to reduce as countries develop, likely because large cities in developed nations attract low SES populations from other regions and countries looking for jobs (Caro & Lenkeit, 2012). That is, the SES advantage of students in urban areas reduces in developed contexts. The hypothesis in the current study is that students in rural areas perform worse than students in urban areas in Armenia.

Statistical model

The hypothesis is evaluated with the following regression model.

$$y_{ij} = \beta_0 + \beta_1 URBAN_{\ \ j} + e_{ij} \quad \text{...(5)}$$

Estimates of β_1 denote the gap in performance between urban and non-urban schools. A positive estimate indicates that students in urban schools perform better than students in non-urban schools. A negative estimate indicates that students in urban schools perform worse than students in non-urban schools. A positive estimate is expected in Armenia.

Results

Table 5 records regression coefficients (β_1) capturing the urban-rural gap in mathematics and science achievement. In general, the gap was positive across countries. That is, students in urban areas performed better than students in non-urban areas. In 2011 and 2015, the achievement gap was largest in Iran and lowest in the Russian Federation.

Table 5. The urban-rural gap in mathematics and science achievement

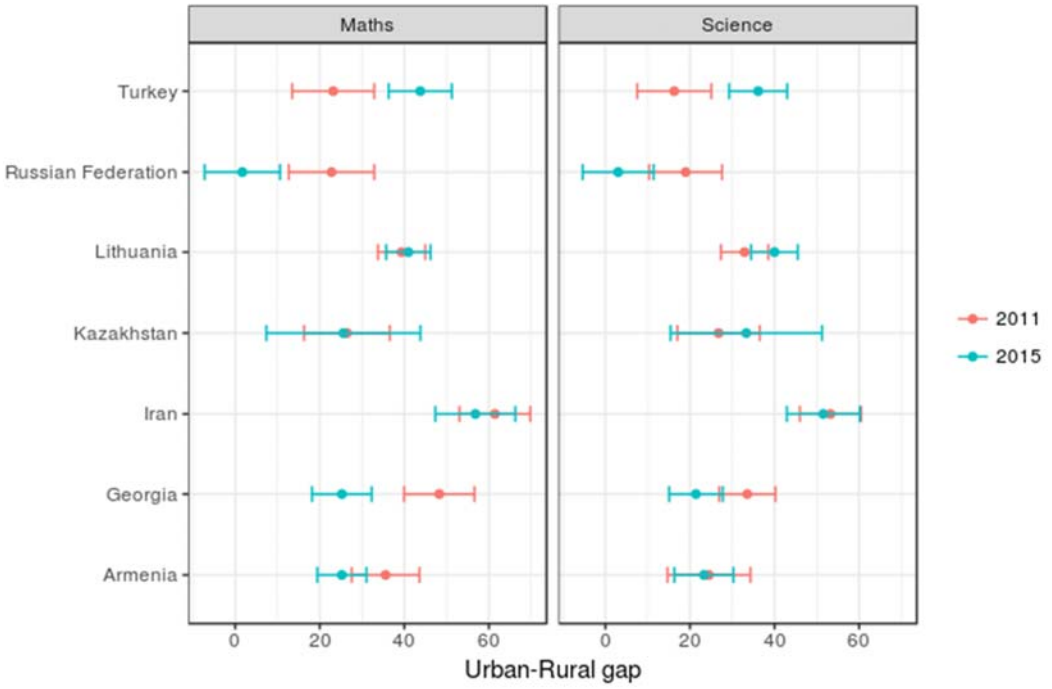
	Mathematics		Science	
Education system	2011	2015	2011	2015
Armenia	**35.57**	**25.23**	**24.50**	**23.30**
Georgia	**48.28**	**25.23**	**33.60**	**21.40**
Iran	**61.41**	**56.80**	**53.24**	**51.53**

Kazakhstan	**26.44**	**25.60**	**26.77**	**33.32**
Lithuania	**39.37**	**40.95**	**32.92**	**39.98**
Russian Federation	**22.79**	1.69	**18.98**	3.02
Turkey	**23.20**	**43.77**	**16.30**	**36.12**

Note: Coefficients in bold are statistically significant ($p < 0.05$).

Figure 14 displays the urban-rural gap (β_1) and its associated standard error across countries in 2011 and 2015. Positive values indicate lower performance of students in non-urban areas. In Armenia, the gap in math achievement remained relatively stable (see also Table 5). However, the gap in math achievement reduced from 2011 to 2015. The evidence supported the hypothesis.

Figure 14. The gap between urban and non-urban schools in student achievement



Note. The figure plots estimates of β_1(dots) and associated standard errors (error bars).

The urban-rural gap explained by school resources

This research question evaluates whether school resources help explain performance differences between schools in rural and urban areas. But before examining the role of school resources in the urban-rural gap, we evaluate whether school resources are related to student achievement.

Hypothesis

Although research in economically developed countries (e.g., Finland) shows limited effects of school resources on student achievement (Häkkinen, Kirjavainen, & Uusitalo, 2003), other studies report a facilitating role of school resources in developing countries (e.g., León & Valdivia, 2015), especially if they resulted in changes in children's daily experiences at school (e.g., Greenwald,

Hedges, & Laine, 1996; Ganimian, & Murnane,2016). Accordingly, it is expected that in Armenia, school resources such as resources for instruction are associated with higher student achievements.

Statistical model

The hypothesis was tested with scales reflecting the availability of school resources for mathematics (RESM) and science instruction (RESS). The scales were based on responses from principals relating to the availability of general school resources (e.g., conditions of school buildings, grounds, heating systems) and subject specific resources for instruction (e.g., computer hardware and software, and specialised teachers). Scale constituent items and scale development methods are described in Appendix A. The scales were not available in TIMSS 2003. Therefore, the hypothesis was tested with data from 2011 and 2015.

The following regression model evaluates the association between mathematics achievement and RESM.

$$y_{ij} = \beta_0 + \beta_1 RESM_{ij} + e_{ij} \quad \ldots(6)$$

A similar model was estimated for science achievement by substituting *RESM* for *RESS*. Parameter $\beta_1$measures the relationship between student achievement and school resources. Positive estimates are expected.

Results

Table 6 reports regression coefficients (β_1)for the association between student achievement (i.e., mathematics and science) and resources for instruction (i.e., RESM and RESS).

Table 6. Regression of student achievement on school resources for instruction

	Mathematics		Science	
Education system	2011	2015	2011	2015
Armenia	4.16	1.76	3.74	2.39
Georgia	4.73	2.44	1.97	2.42
Iran	**12.08**	**10.37**	**10.13**	**9.46**
Kazakhstan	3.23	-0.95	2.48	-2.42
Lithuania	3.32	-1.56	2.47	-1.68
Russian Federation	3.15	3.83	**3.83**	3.76
Turkey	**13.31**	6.32	**11.07**	5.03

Note. Regression coefficients in bold are statistically significant ($p < 0.05$).

The availability of school resources was positively related to mathematics and science performance in Armenia. However, coefficients were not statistically significant. The association with schools resources was positive and statistically significant in Iran and Turkey for mathematics and science. And it was statistically significant for science achievement in the Russian Federation.

Because the association with school resources was not statistically significant in Armenia, we did not proceed to evaluate whether school resources contribute to explaining the urban-rural gap in student performance. Unreported analysis, however, showed that the urban-rural gap remains stable once school resources were taken into account in Armenia and even in Iran and Turkey, where the association with school resources was statistically significant. That is, the evidence did not provide support for our hypothesis.

The urban-rural gap explained by school SES

The fifth and last research question evaluates the extent to which the urban-rural gap is explained by SES.

Hypothesis

As explained earlier, research shows that urban-rural gaps in student achievement are partly explained by socio-economic regional differences, particularly, in developing contexts, where urban areas are related with higher SES and rural areas to lower SES. Accordingly, we expect the urban-rural gap to be partly explained by the student and school SES.

Statistical model

The hypothesis is assessed with the following regression model.

$$y_{ij} = \beta_0 + \beta_1 RURAL_j + \beta_2 SES_{ij} + \beta_3 \underline{SES}_j + e_{ij} \quad \ldots(7)$$

Specifically, we compare estimates of β_1 in Equation 5 and Equation 7, once SES is controlled for. The hypothesis is supported if β_1 reduces from Equation 5 to Equation 7. That is, if the urban-rural gap reduces once SES is taking into account.

Results

Table 7 records estimates of β_1 in Equation 7, that is, the urban-rural gap unexplained by SES. Figure 15 displays estimates of β_1 and its associated standard error.

In 2011, no evidence of underperformance in rural areas was found once SES was taken into account. That is, the urban-rural gap was fully explained by the SES context across countries and also in Armenia. The evidence provided support for the hypothesis. In fact, the urban-rural gap reversed and favoured significantly rural schools in Turkey. Put differently, rural schools performed better than urban schools with comparable SES contexts in Turkey.

Table 7. The urban-rural gap after controlling for the student and school SES

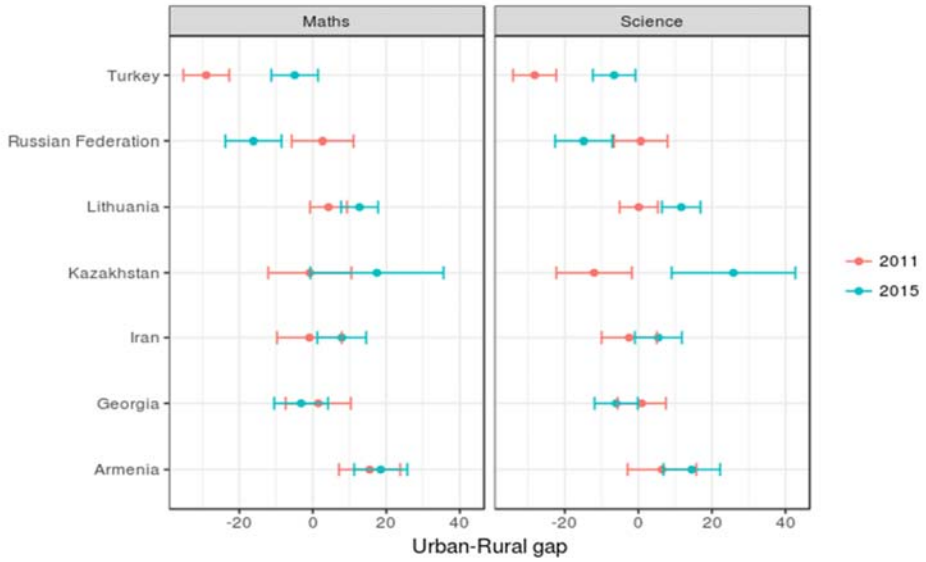
Education system	Mathematics		Science	
	2011	2015	2011	2015
Armenia	15.44	**18.48**	6.41	14.52
Georgia	1.48	-3.20	0.92	-6.04
Iran	-0.91	7.87	-2.51	5.43
Kazakhstan	-0.82	17.44	-12.04	25.86
Lithuania	4.26	**12.71**	0.11	**11.65**

Russian Federation	2.66	**-16.15**	0.64	**-14.89**
Turkey	**-28.98**	-4.93	**-28.21**	-6.59

Note. Regression coefficients in bold are statistically significant ($p < 0.05$).

In 2015, the urban-rural gap in Armenia and Lithuania was positive for science achievement even after accounting for SES (see Table 7 and Figure 15). That is, other school characteristics beyond SES explained underperformance of schools in rural areas. In the Russian Federation the urban-rural gap was negative once SES was controlled for. That is, schools in rural areas performed better than schools in urban areas with comparable SES contexts.

Figure 15. The urban-rural gap after controlling for student and school SES



Note. The figure plots estimates of β_1(dots) and associated standard errors (error bars).

Discussion and policy implications

Responses to research questions are discussed below.

1. What is the relationship between SES and academic achievement? How has it changed over time?

Students from higher SES backgrounds in Armenia performed better in mathematics and science than students coming from lower SES families. The SES gap in student achievement has increased from 2003 to 2011-2015. The widening achievement gap across SES groups is alarming and deserves attention from policymakers. The problem was aggravated because the SES gap in Armenia not only represented differences between wealthier and less affluent families but also differences between those living in poverty (30%) and those not (70%). Students living below the poverty line performed worse academically in secondary school, which would have long-lasting consequences on their educational and economic opportunities as adults. With that, inequalities and poverty are reproduced across generations.

The relationship between student achievement and SES, however, is not deterministic and there are many students from similar SES backgrounds performing very differently in the mathematics and science test. Thus, there should be other mechanisms apart from SES explaining differences in student performance.
The education system in Armenia is relatively ineffective for serving students from different SES backgrounds in comparison with other countries in the region. For example, if we compare two students with similar SES backgrounds but living in different countries, the one living in Armenia tends to perform worse in mathematics and science than his/her counterpart living in the Russian Federation, Turkey, or Kazakhstan.

2. Does the school SES play a role in student achievement above and beyond the role of family SES? Or, in other words, are low SES students in *double jeopardy* for coming from low SES backgrounds and attending low SES schools?

Independently of the student SES, the school SES (i.e., the socio-economic composition of the student intake) played a role in student performance in Armenia. Particularly, low SES students performed better in mathematics and science if attending a high SES school than in a low SES school. From this perspective, low SES students were in *double jeopardy*, first for coming from disadvantaged family backgrounds and secondly for attending low SES schools. The evidence supporting the double jeopardy hypothesis was stronger in 2003 than in 2011 and 2015. The mechanisms responsible for the school SES composition effect on student achievement deserve the attention of further research. Importantly, they may not relate only to ability and SES peer characteristics of the school's student intake, but also to school quality characteristics (e.g., teaching approaches, classroom management, disciplinary climate) that vary across schools and are captured by the school SES effect.
In terms of policy, the evidence generally points to the importance of improving SES living conditions for the sustainability of educational and economic outcomes. More specifically related to equity, the evidence suggests that policies targeted at low SES families and low SES schools will contribute to reducing the gap in student achievement. Armenia has the highest GDP in the Caucasus region and the lowest rates of education expenditures in the region. Greater efforts can be made for the design and implementation of cost-effective interventions targeted to students and schools in socio-economic disadvantage. Instead, the national strategy to "ensuring the effectiveness and efficiency of the system and equal access to education **according to the aspirations and abilities of every citizen**" as documented in the country review of the Education for All may work against the principle of equity; it will put these already in disadvantage (low SES families and low SES schools) in dire jeopardy and increase the achievement gap.

3. What is the student achievement gap between urban and rural areas? How has it changed over time?

Students in schools located in rural areas performed worse in mathematics and science than students in urban areas in Armenia. The urban-rural gap in student achievement has remained relatively stable between 2011 and 2015.

Although the urban-rural gap did not widen from 2011 to 2015, it still exists and requires mitigation. In the Armenian contexts, the gap could be due to the school size and teaching quality

differences in these regions. The planned excellence centers escape rural areas, which may exacerbate the gap. From successful experience to promote equity and shared progress such as Shanghai in China, it is advised to discard key school systems (i.e., not to label schools based on students' achievements, or to direct resources to schools with the best performance). Instead, it is helpful to partner high performing schools with low performing schools in an entrusted management system where low performing schools can learn from and progress together with high performing schools (e.g., Liang, Kidwai, & Zhang, 2016).

4. Is the urban/rural gap explained by the availability of school resources for student instruction?

There was no evidence that student performance in urban and rural areas was explained by the availability of resources for student instruction (e.g., school building conditions, library materials, and computers). In fact, no evidence was found that school resources play a role in student achievement in Armenia. School resources were related to student achievement in mathematics and science in Iran and Turkey. But even in these countries school resources did not explain the achievement gap between schools in rural and urban areas.
The lack of school resources effect could be due to how availability of resources was measured. The questions were formulated as how much the school's capacity to provide instruction is affected by a shortage or inadequacy of several resources in the principal questionnaire. Principals may hold different standards as what level of resources should not affect instruction (with these in rural areas having lower expectation and standard, compared with urban areas). Better and more objective measures on availability of resources are needed to rebut or replicate the current results. Research highlighted that school resources enhance student achievements only if these resources truly change students' everyday life (Ganimian, & Murnane, 2016), thus the Armenian authority may deliberate on resources with a positive impact on students' everyday life and carry out targeted provisions.

5. Is the urban-rural gap explained by the SES composition of the school student intake?

The urban-rural gap mathematics and science achievement was explained by the student and school SES in 2011 and partially explained by the student and school SES in 2015. That is, students in rural areas performed worse in mathematics and science fully or in part because of their lower student and school SES. In 2011, students in rural and urban schools with comparable SES levels performed similarly in mathematics and science, yet the gap does not close fully in 2015. Interestingly, in the Russian Federation and Turkey the urban-rural gap favoured students in rural areas once SES was taken into account, where students in rural schools performed better than students in urban schools with comparable SES levels.
SES appears to be a key equaliser for achievement differences between schools in rural and urban areas in Armenia, although it does not fully explain the gap in 2015. As mentioned earlier, however, SES may not only reflect the socio-economic conditions of families and schools, but also differences in school quality provision across schools with different SES levels. Further research could examine the part of the urban-rural gap explained by SES and the part explained by school quality provision with more appropriate data.

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Appendix A: The TIMSS datasets

Sample

The data was sourced from Grade 8 TIMSS 2003, 2011, and 2015. TIMSS administered tests on mathematics and science achievement. Additionally, it collected data on student, teachers, principals, through questionnaires. Sample sizes for education systems considered in this report are reported in Table A1.

Table A1. Sample size by education system

Education system	2003	2011	2015
Armenia	5726	5846	5060
Georgia		4563	4035
Iran	4942	6029	6130
Kazakhstan		4390	4887
Lithuania	4964	4747	4347
Moldova	4033		
Russian Federation	4667	4893	4780
Turkey		6928	6079

Variables

Variables considered in this report are described in this section. For further details on scale development consult Martin and Mullis (2013).

Mathematics achievement (MATH): Student achievement in mathematics is derived from a test with a strong curricular focus that assessed four content domains (number, algebra, geometry, and data and chance) and three cognitive domains (knowing, applying, and reasoning). Students responded to a sub-sample of items from the entire item pool following a matrix-sampling design. Item response theory (IRT) scaling procedures and plausible variables methodology were employed to estimate five plausible math scores that reflected uncertainty in individual score estimation. Scores were allowed to vary between 0–1,000 but typically ranged between 300 and 700. Scores are comparable across TIMSS cycles. They were scaled to have a mean of 500 and a standard deviation of 100 across participating countries in TIMSS 1995.

Science achievement (SCIENCE): Student achievement in science is derived from a test with a strong curricular focus that assessed four content domains (biology; chemistry; physics; and earth science) and three cognitive domains (knowing, applying, and reasoning). Students responded to a sub-sample of items from the entire item pool following a matrix-sampling design. Item response theory (IRT) scaling procedures and plausible variables methodology were employed to estimate five plausible math scores that reflected uncertainty in individual score estimation. Scores were allowed to vary between 0–1,000 but typically ranged between 300 and 700. Scores are comparable

across TIMSS cycles. They were scaled to have a mean of 500 and a standard deviation of 100 across participating countries in TIMSS 1995.

Family socio-economic status (SES). The methodology for measuring SES is presented in this report. The SES measure was scaled to have a mean of 0 in for Armenian Grade 8 students participating in TIMSS 2011.

Parental education (PARED): Highest level of education attained by either parent (1: some primary, lower secondary or no school; 2: lower secondary; 3: upper secondary; 4: post-secondary but not university; 5: university or higher).

Number of books (BOOKS): Number of books at home (1: none or very few [0-10 books]; 2: enough to fill one shelf [11-25 books]; 3: enough to fill one bookcase [26-100 books]; 4: enough to fill two bookcases [101-200 books]; 5: enough to fill three or more bookcases [more than 200 books]).

Home possessions (HOME): Possession of computer and/or desk at home (0%: no computer or desk; 50%: computer or desk at home; 100%: computer and desk at home).

School location (URBAN): Principals were asked for a description of the school location: urban, suburban, medium size, small town or remote rural. Schools in urban areas were classified with a value of 1, and the rest with a value of 0. The question was not available in TIMSS 2003.

Availability of school resources for mathematics instruction (RESM): The scale is based on principals' responses on how much the school's capacity to provide instruction is affected by a shortage or inadequacy of the following (1: not at all, 2: a little, 3: some, 4: a lot):

A. General School Resources: 1) Instructional materials (e.g., textbooks); 2) Supplies (e.g., papers, pencils); 3) School buildings and grounds; 4) Heating/cooling and lighting systems; 5) Instructional space (e.g., classrooms); 6) Technologically competent staff.

B. Resources for Mathematics Instruction: 1) Teachers with a specialization in mathematics; 2) Computers for mathematics instruction; 3) Computer software for mathematics instruction; 4) Library materials relevant to mathematics instruction; 5) Audio-visual resources for mathematics instruction; and 6) Calculators for mathematics instruction.

Using IRT partial credit scaling, responses were placed on a scale constructed so that the mean scale score across all TIMSS countries was 10 and the standard deviation was 2 (Martin and Mullis, 2013). Higher values indicate that schools were less affected by shortages or inadequacy of resources. That is, higher values in the scale reflect greater availability of schools resources for mathematics instruction.

Availability of school resources for science instruction (RESS): The scale is based on principals' responses on how much the school's capacity to provide instruction is affected by a shortage or inadequacy of the following (1: not at all, 2: a little, 3: some, 4: a lot):

A. General School Resources: 1) Instructional materials (e.g., textbooks); 2) Supplies (e.g., papers, pencils); 3) School buildings and grounds; 4) Heating/cooling and lighting systems; 5) Instructional space (e.g., classrooms); 6) Technologically competent staff.

B. Resources for Science Instruction: 1) Teachers with a specialization in science; 2) Computers for science instruction; 3) Computer software for science instruction; 4) Library materials relevant to science instruction; 5) Audio-visual resources for science instruction; 6) Calculators for science instruction; 7) Science equipment and materials.

Using IRT partial credit scaling, responses were placed on a scale constructed so that the mean scale score across all TIMSS countries was 10 and the standard deviation was 2 (Martin and Mullis, 2013). Higher values indicate that schools were less affected by shortages or inadequacy of resources. Put differently, higher values in the scale reflect greater availability of schools.

Descriptive statistics

Table A2. Average values (Mean) and standard errors (s.e.)

Education system	MATH					
	2003		2011		2015	
	Mean	s.e.	Mean	s.e.	Mean	s.e.
Armenia	478.13	(3.00)	466.59	(2.73)	471.46	(3.17)
Georgia			431.14	(3.76)	453.20	(3.44)
Iran	411.45	(2.35)	414.96	(4.30)	436.35	(4.64)
Kazakhstan			486.95	(3.97)	527.81	(5.29)
Moldova	459.89	(4.05)				
Lithuania	501.62	(2.46)	502.37	(2.51)	511.31	(2.77)
Russian Federation	508.04	(3.71)	538.98	(3.56)	538.00	(4.65)
Turkey			452.49	(3.90)	457.63	(4.74)

Education system	SCIENCE					
	2003		2011		2015	
	Mean	s.e.	Mean	s.e.	Mean	s.e.
Armenia	461.27	(3.47)	436.92	(3.12)	460.17	(3.28)
Georgia			419.94	(2.95)	443.17	(3.12)
Iran	453.43	(2.33)	474.39	(4.02)	456.42	(4.01)
Kazakhstan			489.91	(4.26)	532.59	(4.45)
Moldova	472.42	(3.37)				
Lithuania	519.38	(2.14)	513.87	(2.56)	519.11	(2.78)
Russian Federation	513.62	(3.68)	542.46	(3.25)	544.12	(4.21)
Turkey			482.99	(3.42)	493.40	(4.02)

	SES					
	2003		2011		2015	
Education system	Mean	s.e.	Mean	s.e.	Mean	s.e.
Armenia	0.28	(0.04)	0.50	(0.03)	0.00	(0.03)

Georgia			0.32	(0.04)	0.50	(0.04)
Iran	-1.12	(0.05)	-0.80	(0.06)	-0.51	(0.06)
Kazakhstan			0.24	(0.04)	0.26	(0.05)
Moldova	-0.22	(0.04)				
Lithuania	0.56	(0.04)	0.53	(0.03)	0.56	(0.03)
Russian Federation	0.69	(0.05)	0.79	(0.04)	0.57	(0.03)
Turkey			-0.88	(0.05)	-0.64	(0.06)

Education system	HOME					
	2003		2011		2015	
	Mean	s.e.	Mean	s.e.	Mean	s.e.
Armenia	41.88	(0.65)	64.97	(0.95)	62.51	(0.66)
Georgia			68.35	(0.80)	73.12	(0.94)
Iran	38.66	(1.26)	55.59	(1.56)	61.66	(1.13)
Kazakhstan			76.80	(1.31)	79.54	(1.09)
Moldova	49.86	(0.84)				
Lithuania	72.72	(0.85)	97.33	(0.27)	85.54	(0.55)
Russian Federation	61.35	(1.06)	92.15	(0.68)	87.51	(0.61)
Turkey			62.11	(1.37)	64.95	(1.31)

	URBAN			
	2011		2015	
Education system	Mean	s.e.	Mean	s.e.
Armenia	0.16	(0.02)	0.20	(0.03)
Georgia	0.24	(0.03)	0.31	(0.04)
Iran	0.29	(0.03)	0.31	(0.03)
Kazakhstan	0.18	(0.03)	0.13	(0.02)
Lithuania	0.33	(0.03)	0.35	(0.03)

Russian Federation	0.18	(0.02)	0.31	(0.03)
Turkey	0.35	(0.02)	0.42	(0.03)

Education system	RESM				RESS			
	2011		2015		2011		2015	
Armenia	Mean	s.e.	Mean	s.e.	Mean	s.e.	Mean	s.e.
Georgia	10.58	(0.11)	10.86	0.14	10.52	(0.10)	10.78	(0.13)
Iran	10.18	(0.11)	10.5	0.1	10.11	(0.10)	10.57	(0.12)
Kazakhstan	8.81	(0.09)	9.05	0.1	8.83	(0.09)	9.14	(0.11)
Moldova	10.15	(0.20)	10.2	0.18	10.20	(0.19)	10.29	(0.20)
Lithuania	10.27	(0.10)	10.22	0.13	10.29	(0.10)	10.16	(0.14)
Russian Federation	10.15	(0.13)	10.15	0.09	10.15	(0.13)	10.28	(0.10)
Turkey	8.44	(0.09)	8.42	0.11	8.32	(0.09)	8.42	(0.11)

Table A3. Parental education (PARED): percentage of students in each category (%) and standard errors (s.e.)

Education system		2003					2011				
		1	2	3	4	5	1	2	3	4	5
Armenia	%	0.83	2.15	24.22	21.76	51.04	0.03	3.32	14.51	23.10	59.05
	s.e.	(0.16)	(0.38)	(1.10)	(0.94)	(1.52)	(0.02)	(0.36)	(0.89)	(0.98)	(1.35)
Georgia	%						0.56	4.01	31.67	30.94	32.83
	s.e.						(0.18)	(0.60)	(1.43)	(1.25)	(1.47)
Iran	%	43.39	21.89	14.53	9.97	10.21	24.99	26.30	12.46	21.09	15.17
	s.e.	(1.64)	(0.80)	(0.81)	(0.74)	(0.76)	(1.28)	(0.97)	(0.68)	(1.12)	(1.18)
Kazakhstan	%						0.10	7.63	22.12	34.59	35.56
	s.e.						(0.05)	(0.67)	(1.05)	(1.10)	(1.55)
Lithuania	%	0.93	2.04	29.94	30.78	36.32	0.44	6.51	29.20	39.85	23.99
	s.e.	(0.19)	(0.31)	(1.29)	(1.04)	(1.63)	(0.18)	(0.50)	(1.13)	(1.11)	(1.12)
Moldova	%	10.07	16.57	21.30	17.87	34.20					
	s.e.	(0.84)	(0.94)	(1.07)	(1.01)	(1.42)					
Russian Federation	%	0.40	6.34	23.54	26.05	43.68	0.24	6.92	12.50	31.21	49.12
	s.e.	(0.12)	(0.52)	(1.20)	(1.51)	(2.26)	(0.15)	(0.58)	(1.04)	(1.02)	(1.54)
Turkey	%						48.88	14.59	23.21	4.74	8.59
	s.e.						(1.59)	(0.59)	(0.86)	(0.38)	(0.98)

Note. Parental education levels: 1= some primary, lower secondary or no school; 2= lower secondary; 3= upper secondary; 4= post-secondary but not university; 5= university or higher.

Table A4. Number of books at home (BOOKS): percentage of students in each category (%) and standard errors (s.e.)

Education system		2003					2011					2015				
		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Armenia	%	15.14	23.77	28.12	13.30	19.67	12.39	22.65	32.67	15.60	16.69	11.89	29.22	32.31	14.92	11.66
	s.e.	(0.94)	(0.87)	(0.71)	(0.64)	(1.00)	(0.67)	(0.73)	(0.83)	(0.60)	(0.78)	(0.70)	(0.77)	(0.76)	(0.61)	(0.51)
Georgia	%						12.18	23.93	27.16	17.22	19.52	10.32	22.51	27.22	17.98	21.97
	s.e.						(0.97)	(0.93)	(1.11)	(0.76)	(1.13)	(0.89)	(1.12)	(0.92)	(0.93)	(1.15)
Iran	%	39.33	30.85	17.46	5.11	7.25	33.83	32.52	18.62	6.44	8.59	26.67	32.86	22.07	8.47	9.93
	s.e.	(1.35)	(0.79)	(0.81)	(0.32)	(0.54)	(1.22)	(0.72)	(0.78)	(0.41)	(0.60)	(1.30)	(0.90)	(0.80)	(0.57)	(0.63)
Kazakhstan	%						14.42	39.17	29.26	9.03	8.12	12.62	40.02	28.31	12.01	7.06
	s.e.						(0.97)	(1.26)	(1.07)	(0.61)	(0.82)	(0.94)	(1.92)	(1.41)	(1.21)	(0.84)
Lithuania	%	10.16	29.58	34.17	14.54	11.55	13.16	29.67	33.42	13.74	10.00	13.13	31.47	31.57	13.59	10.24
	s.e.	(0.70)	(1.12)	(0.91)	(0.68)	(0.81)	(0.66)	(0.84)	(0.91)	(0.59)	(0.72)	(0.68)	(1.03)	(1.01)	(0.82)	(1.03)
Moldova	%	23.35	36.74	23.14	9.11	7.66										
	s.e.	(1.15)	(1.22)	(0.98)	(0.64)	(0.76)										
Russian Federation	%	4.20	16.67	32.16	25.86	21.10	6.17	27.29	35.65	17.44	13.45	7.38	30.38	38.51	15.01	8.72
	s.e.	(0.49)	(1.07)	(1.35)	(0.94)	(1.30)	(0.47)	(1.11)	(0.89)	(0.58)	(0.72)	(0.68)	(1.06)	(0.86)	(0.65)	(0.50)
Turkey	%						19.51	36.95	26.60	10.20	6.74	16.35	34.82	30.05	10.61	8.17
	s.e.						(0.93)	(0.97)	(0.66)	(0.62)	(0.59)	(0.81)	(1.20)	(0.83)	(0.70)	(0.68)

Note. Number of books at home: 1= none or very few (0-10 books); 2= enough to fill one shelf (11-25 books); 3= enough to fill one bookcase (26-100 books); 4= enough to fill two bookcases (101-200 books); 5= enough to fill three or more bookcases (more than 200 books).

Table A5. Missing data analysis: Percentage of data missing

Education system	SES			URBAN		BOOKS			PARED			HOME			RESM		RESS	
	2003	2011	2015	2011	2015	2003	2011	2015	2003	2011	2015	2003	2011	2015	2011	2015	2011	2015
Armenia	13.50	14.49	24.51	1.11	3.99	2.93	1.20	3.26	11.32	13.62	23.64	4.77	0.63	3.36	1.69	4.76	1.69	4.76
Georgia		23.25	23.97	4.97	1.16		1.12	0.57		22.05	23.67		0.92	0.55	3.57	2.21	3.57	2.21
Iran	5.91	4.25	4.68	0.51	0.00	0.91	0.32	0.39	4.11	3.83	3.95	1.74	0.25	0.52	0.35	0.44	0.35	0.44
Kazakhstan		9.00	7.67	0.00	0.27		0.18	0.20		8.59	7.37		0.50	0.20	0.00	0.90	0.00	0.90
Moldova	16.12					0.84			15.17			0.72						
Lithuania	25.34	20.98	20.31	3.86	0.00	10.17	0.40	0.41	25.14	20.81	20.11	9.97	0.40	0.46	6.53	0.00	6.53	0.00
Russian Federation	10.84	10.91	13.28	0.00	0.00	0.26	0.25	0.10	10.37	10.65	13.18	0.60	0.16	0.10	0.00	1.21	0.00	0.82
Turkey		3.93	5.03	1.04	0.00		0.53	0.89		3.49	4.64		0.10	0.48	0.62	0.00	0.62	0.00

Appendix B: Additional results

Figure B1. TIMSS 2003: Socio-economic gradients in mathematics

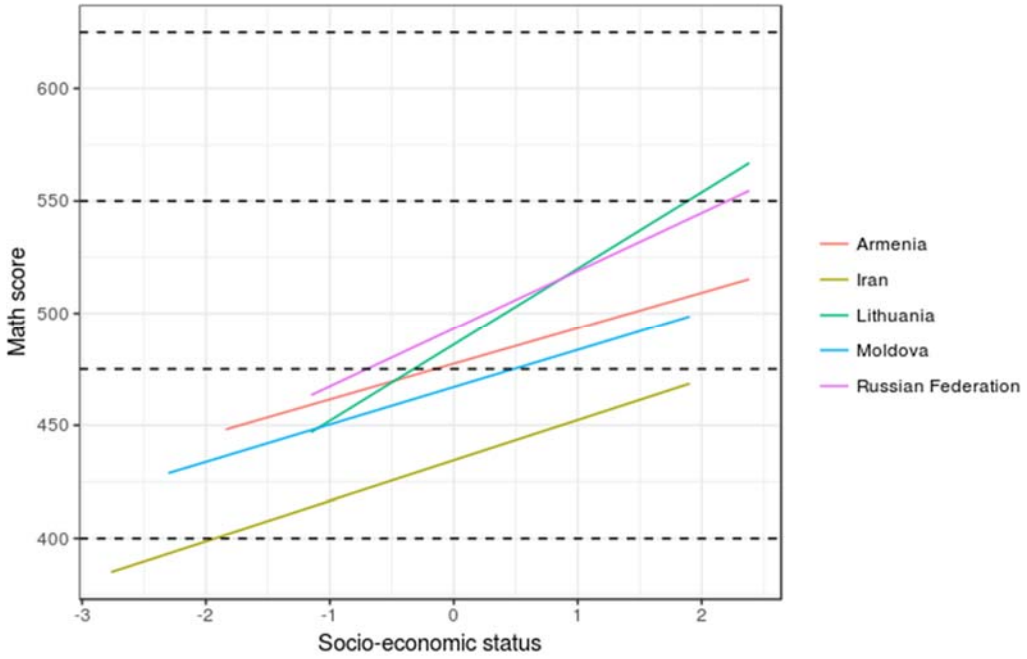

Figure B2. TIMSS 2003. Socio-economic gradients in science

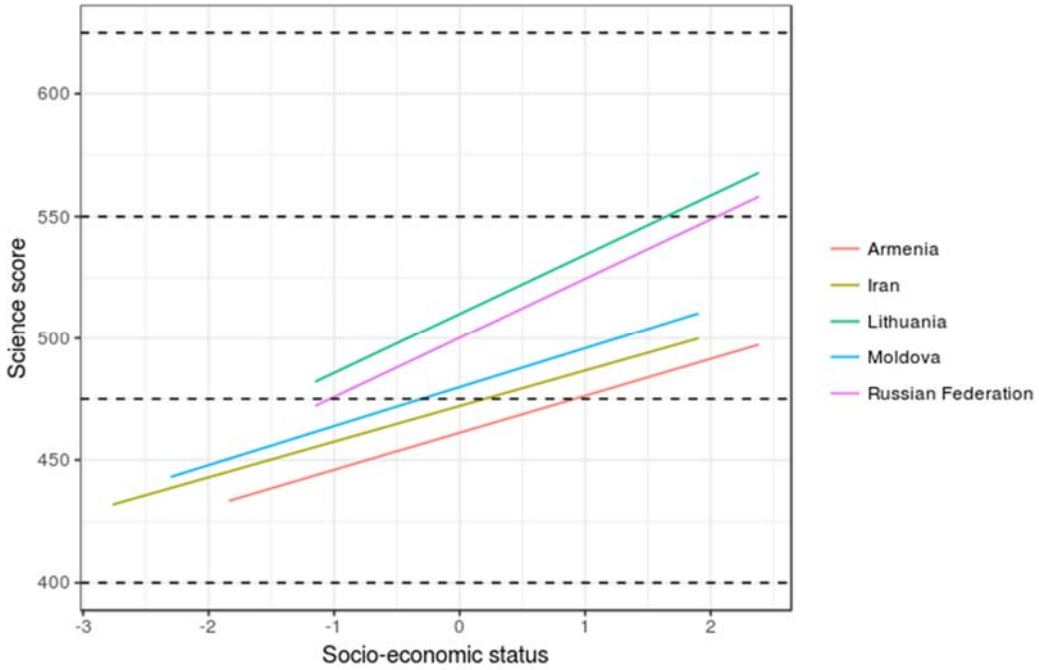

Figure A3. TIMSS 2011: Socio-economic gradients in math achievement

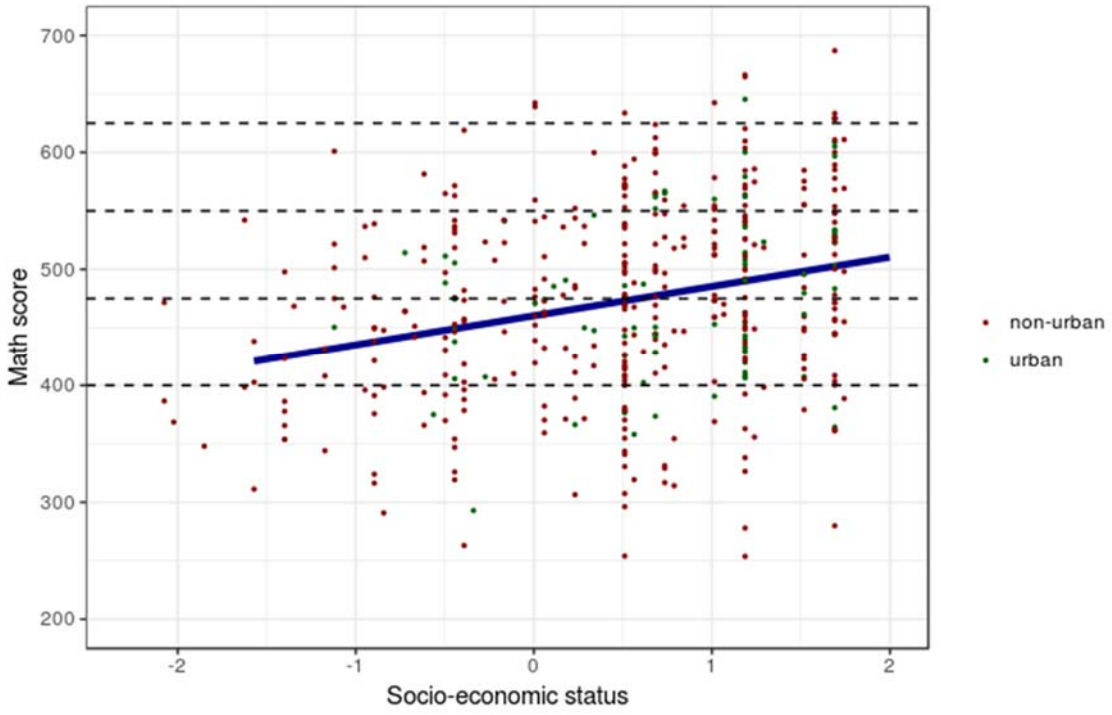

Figure A4. TIMSS 2011: Socio-economic gradients in science achievement

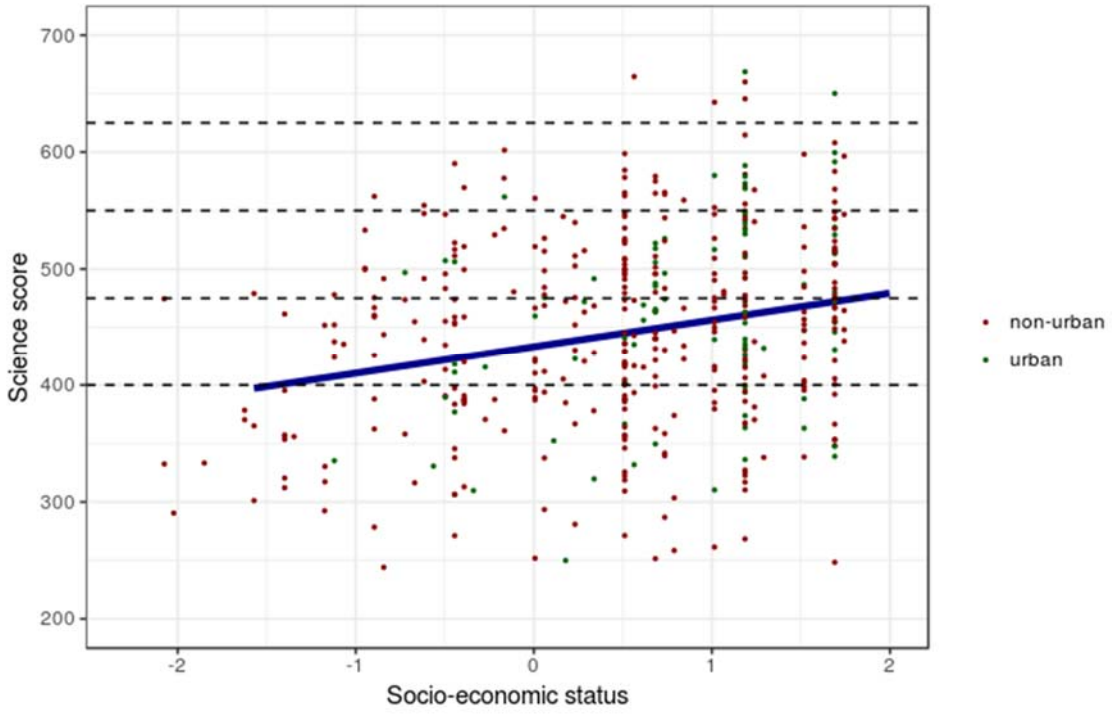

Figure A5. TIMSS 2015: Socio-economic gradients in math achievement

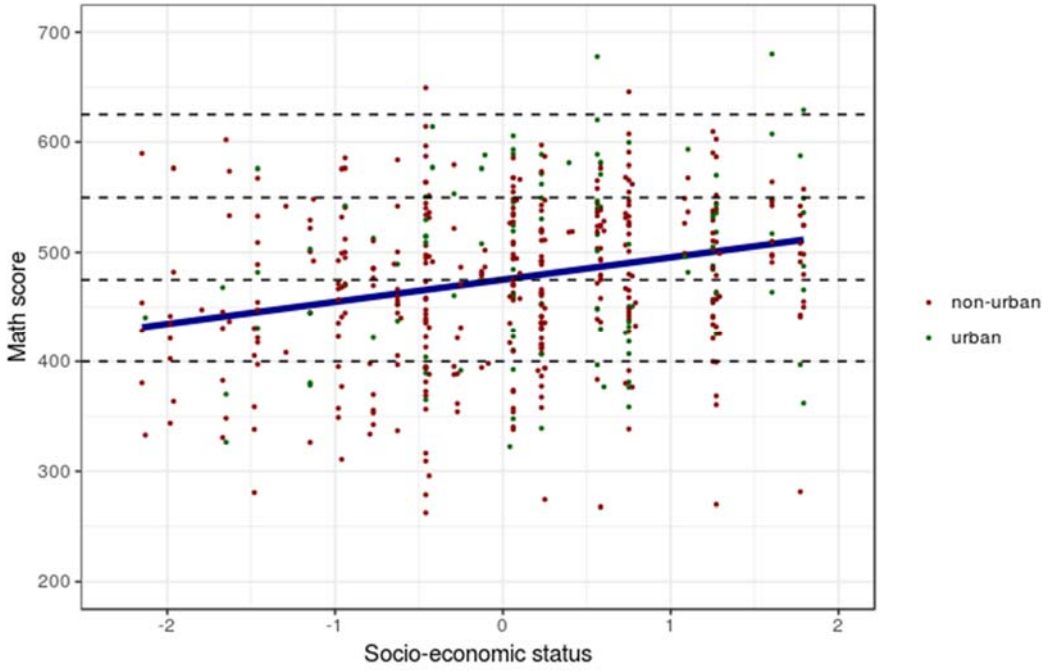

Figure A6. TIMSS 2015: Socio-economic gradients in science achievement