The Journey of Mathematically Gifted Students in Chile from Primary School to Higher Education*

Extended Abstract

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Math talent in childhood is highly predictive of students' innovation potential and labor market success (Agarwal and Gaule, 2020; Bell et al., 2019; Doty et al., 2022; Kell et al., 2013). However, many students who are gifted at math, especially those from lower-income families and women, may have more limited academic and career success and be less likely to become inventors than their richer peers (Avery and Hoxby, 2013; Bell et al., 2019, 2018; Das et al., 2022; Ellison and Swanson, 2016). Disparities in math talent emerge early in student's careers, sustain or grow during the school years (Bell et al., 2019; Das et al., 2022; Ellison and Swanson, 2016; Fryer and Levitt, 2010; Fryer Jr and Levitt, 2004), lead to less attractive college choices (Avery and Hoxby, 2013), and to lower participation in Science, Technology, Engineering, and Math (STEM) higher education and careers (Kirkeboen et al., 2016).

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Lost talent is problematic for individuals, as gifted students may forgo a lifetime of high earnings and professional realization, and also from an economy-wide perspective due to its impact on talent allocation (Hsieh et al., 2019) and innovation (Bell et al., 2019). Bell et al. (2019) show that if the innovation gaps between women and men and low-income and high-income kids were closed, innovation in America would quadruple.

Much of the evidence on high-performing students comes from the US and to a lesser extent from Europe; however, over 75 percent of school-age children live in developing countries[1], where talent misallocation may be even higher than in rich countries (Ugarov, 2019). Agarwal and Gaule (2020) study International Mathematical Olympiad participants and show that while the highest levels of mathematical excellence are predictive of research and innovation productivity in later years, equally high-performing students from poor countries are less likely to participate in knowledge production and to be less productive when they do so. If most gifted students in low and middle-income countries (LMICs) do not have the opportunity to develop their talent to these levels, then the lost innovation potential in LMICs greatly exceeds these estimates. Das et al. (2022), studying the broader student population, suggest that this "extensive margin" of talent loss is large. Tracking children longitudinally across 5 LMICs, they find that test score disparities between low and high income children appear early (by age 8), and that low income children in all five countries are far less likely to pursue higher education as compared to higher income children with similar test scores.

In this paper, we use panel data from Chile[2] to study educational trajectories of high-performing math students. Children across the country are administered math and language tests (Education Quality Measurement System, or SIMCE) at multiple points during their school careers, starting in grade 4. We track their trajectories through school and higher education placement, including how outcomes differ by student gender and income. Student income is measured by an indicator of whether the student is eligi-

[1] Analysis based on data from the World Development Indicators (World Bank Group, 2024).

[2] Chile is officially an OECD country since 2010, just one year before the cohort of students we study took their fourth-grade tests. As such, it can be seen as a "best case" for developing countries. Its education system also has similarities to other systems in Latin America, including those of countries officially considered to be LMICs.

ble for school subsidies (e.g. subsidized lunch). We also use data on whether their school is classified as low, medium, or high socioeconomic status (SES), which is highly correlated with family income of children attending the school. Note that while SIMCE tests are high-stakes for schools, they are low-stakes for students; in fact, students, families, and teachers do not learn individual scores. Hence, these tests are not subject to biases arising from within-school differential test preparation by income or gender differences in performance on competitive or timed tests (Arias et al., 2023; Gneezy et al., 2003).

We focus on the Chilean cohort of students who were in Grade 4 in 2011 and begin entering higher education in 2020. We conduct some analyses both with the full sample of 240,897 students (Table 1) but focus most of the paper on the sample of approximately 5000 students with the top 2.5 percent of scores in the Grade 4 math test in 2011 (Table 2).

First, with the full sample of students, we replicate findings from other countries: we show that in Chile, boys score higher than girls, and that low income kids do worse than their higher income counterparts on math tests. The majority of these differences are established by the first test in Grade 4 and persist over time. The differences become greater at higher percentiles of the distribution, up to the top 1 percent of the distribution. Girls perform approximately 0.075 standard deviations below boys on the 4th grade math test, and this difference is consistent for richer and poor students. Girls are also under-represented at the highest levels of performance: there are about 1.3 boys for every girl in the top 10 percent of scores, rising to 1.4 boys for every girl in the top 1 percent. These differences also grow over time: by 10th grade, the ratio of boys to girls in the top 1 percent has grown to 1.6. While the boys to girls difference is meaningful, the differences are larger by family income: kids who receive a subsidy perform about 0.4 standard deviations below richer kids. Kids who do not receive a subsidy are 3.9 times more likely to score in the top 10 percent on the test, and 4.9 times more likely to score in the top 1 percent. By 10th grade, kids who do not receive a subsidy are 4.5 times as likely to be in the top 1 percent. The differences are even more stark when considering schools classified as being low, medium or high SES. Fourth grade math scores of those going to the lowest SES schools are 1.3 standard deviations lower than those of students going to highest SES schools. Students going to the highest SES schools are 8.4 times more likely to be amongst the top 10 percent of scorers in Grade 4, and over 14.5

times more likely to be amongst the top 1 percent than children going to the poorest schools.

Second, we show that high scores on early grade math exams are meaningful measures of math talent, in that they are highly predictive of performance in the grade 10 math exam, and of higher education outcomes. Students who score in the top 2.5 percent in math in Grade 4, are 23.8 percentage points, or 10.9 times, as likely as students in the bottom 97.5 percent to also be in the top 2.5 percent of the distribution in the 10th grade math exam, and 22.6 percentage points, or about 3.9 times as likely to enroll in a STEM degree in college.

Third, we confirm that in Chile, like in other countries, even controlling for early grade math talent, girls are less likely to take up STEM majors than boys and low-SES kids have worse higher education outcomes, including less participation in STEM, than their richer counterparts.

Fourth, we show that, though mitigated somewhat, these disparities still remain for the most talented students in math. For the top 5000 math performers (approximately the top 2.5 percent of students) in grade 4, controlling for math scores, girls are equally or more likely to go to college than boys but 18.5 percentage points less likely to pursue a STEM degree in a university (average national enrollment in STEM is 14 percent), and 4.5 percentage points less likely to pursue a STEM related degree at a leading university (average national enrollment of 1.3 percent). Additionally, kids who do not receive subsidies are 8 percentage points more likely to pursue higher education (37 percent national enrollment), and 11.2 percentage points more likely to pursue a STEM degree at a leading school.

When adding controls for the SES level of the school, the coefficient on the student subsidy variable remains negative; while it is no longer significant for enrollment in university, it remains significant at the 10 percent level for enrollment in STEM and STEM at a top school. College placement as well as taking up STEM is also highly correlated with the SES of the school. Top Students in the richest schools are 1.4 times as likely to pursue tertiary education, 2.7 times as likely to pursue STEM, and 15.6 times as likely to pursue STEM in elite programs as students in the poorest schools.

Hence, even for students who are highly talented at math, poorer students

have much worse outcomes in terms of university placement and preparation for STEM careers than do richer students. Some of this disadvantage stems from the child and her family circumstances, but the majority of the effect seems to be driven by the differences in the schools that they attend.

We explore reasons for these differences by income, providing exploratory rather than conclusive evidence. Several studies lay out the importance of knowledge (e.g. Avery and Hoxby (2013)), and expectations and self-image (e.g Beaman et al. (2012); Eble and Hu (2022)) for academic outcomes. In Chile, we observe that even controlling for math scores, parental expectations are lower for poor children, although they do rise with math scores. Programs that target expectations and perceptions are worthy of further research. Higher education in Chile is free for students from the bottom 60% of the income distribution; however, knowledge about accessing financial aid and/or cost of coaching classes for college entrance exams or the opportunity costs of remaining out of the labor market may drive decisions for some children (Barrios-Fernández, 2022). Programs that help students navigate financial aid and additional scholarships may change college enrollment decisions even when the cost of college is covered. We also expect that quality of teaching matters, and expect to have data to test this within the next month.

In summary, we find that the extent of lost talent is large, especially for women and poor children. Disparities in math outcomes emerge early, but even within the subset of children who show strong early talent in mathematics, girls and poor students go on to pursue STEM in college, and STEM in top universities at much lower rates than richer boys. For poor children in particular, these disparities stem both from their individual circumstances, and due to the schools they attend. Further research on changing expectations and aspirations, addressing information and financial barriers around university test preparation, financial aid and admissions, and improving the quality of math instruction could inform on how to ensure that a greater share of highly talented children achieve their full potential.

Table 1: Academic Outcomes by Student Demographics (All Students)

	SD from Mean		Porcentage of Enrollment				
	Math 4th	Math 10th	Higher Edu	Uni	STEM	Top Uni	STEM Top Uni
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: Gender							
Female	-0.038	-0.033	0.421	0.292	0.066	0.038	0.010
Male	0.037	0.035	0.389	0.244	0.212	0.032	0.016
Panel B: Type of School							
Low Income	-0.462	-0.594	0.270	0.117	0.092	0.004	0.001
Middle-Low Income	-0.303	-0.434	0.322	0.152	0.111	0.009	0.002
Middle Income	0.002	-0.026	0.410	0.254	0.143	0.021	0.007
Middle-High Income	0.386	0.454	0.487	0.404	0.174	0.048	0.018
High Income	0.835	0.921	0.678	0.648	0.216	0.208	0.079
Panel C: subsidy							
Subsidy	-0.259	-0.363	0.323	0.165	0.111	0.010	0.003
No Subsidy	0.153	0.182	0.453	0.329	0.157	0.050	0.019
Panel D: Population							
Mean	-0.000	-0.000	0.405	0.268	0.140	0.035	0.013
Observations	214880	146283	214880	214880	214880	214880	214880

Notes: Column (1) shows the mean math score in 4th grade, expressed in standard deviations from the mean, for each group of students. Column (2) shows the mean math score in 10th grade, expressed in standard deviations from the mean, for each group of students. Column (3) shows the proportion of students in each group that enrolled in higher education. Column (4) shows the proportion of students in each group that enrolled in universities. Column (5) shows the proportion of students in each group that enrolled in STEM programs. Column (6) shows the proportion of students in each group enrolled in top universities. Column (7) shows the proportion of students in each group enrolled in STEM programs in top universities.

Table 2: Probability of Higher Education Enrollment Outcomes for Highest Performing Students

	(1) Higher Educ	(2) Higher Educ	(3) Any uni	(4) Any uni	(5) STEM uni	(6) STEM uni	(7) Top Uni	(8) Top Uni	(9) Top STEM Uni	(10) Top STEM Uni
Math Score (SD)	0.115***	0.104**	0.134***	0.118***	0.0773*	0.0725*	0.152***	0.122***	0.0920***	0.0771**
	(0.035)	(0.034)	(0.036)	(0.036)	(0.035)	(0.035)	(0.032)	(0.030)	(0.025)	(0.024)
Male	0.0118	0.0138	-0.0183	-0.0150	0.185***	0.187***	-0.0199	-0.0136	0.0445***	0.0478***
	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.012)	(0.011)	(0.009)	(0.009)
Student Subsidy	-0.0808***	-0.0207	-0.139***	-0.0332	-0.125***	-0.0553**	-0.184***	-0.0391*	-0.112***	-0.0313*
	(0.017)	(0.019)	(0.017)	(0.020)	(0.017)	(0.019)	(0.016)	(0.017)	(0.012)	(0.014)
Middle-Low income		0.0584		0.0858*		0.0933*		0.0223		0.00373
		(0.042)		(0.044)		(0.042)		(0.037)		(0.029)
Middle income		0.0846*		0.132**		0.135***		0.0762*		0.0273
		(0.041)		(0.042)		(0.041)		(0.036)		(0.029)
Middle-High income		0.0928*		0.184***		0.201***		0.110**		0.0725*
		(0.042)		(0.043)		(0.042)		(0.037)		(0.029)
High income		0.201***		0.317***		0.215***		0.388***		0.194***
		(0.042)		(0.043)		(0.042)		(0.037)		(0.029)
Constant	0.474***	0.372***	0.408***	0.232**	0.0506	-0.119	-0.0566	-0.188*	-0.0897	-0.159**
	(0.077)	(0.086)	(0.080)	(0.089)	(0.077)	(0.086)	(0.071)	(0.076)	(0.055)	(0.060)
Observations	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000

Notes: This analysis is restricted to the 5000 (approximately 2.5 percent) top performing students in the Grade 4 math exam in 2011. The outcome variable in columns: (1) and (2) is the probability a student enrolls in any higher education (including vocational programs) by 2020; (3) and (4) is the probability of enrolling in any university; (5) and (6) is the probability of enrolling in a STEM program in any university, (7) and (8) is the probability of enrolling in a top university; and (9) and (10) is the probability of enrolling in a STEM program at a top university. The explanatory variables include individual student math scores in fourth grade (expressed in standard deviations from the mean), student gender, whether the student receives school subsidies, and the official SEC categorization of the school. Standard errors are presented in parentheses *: Significant at 10%, **: Significant at 5%, ***: Significant at 1%.

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