Are Teachers Getting Smarter? International Evidence on Changes in Teacher Cognitive Skills and Student Achievement

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Abstract

Teacher cognitive skills shifted notably over the last decade. Using PIAAC Cycles 1-–2 for 25 countries, we document how the level, dispersion, and relative standing of teachers' numeracy and literacy evolved within countries. The descriptive evidence reveals large heterogeneity: some countries saw teacher-skill declines of about one standard deviation, while others improved; and teachers' position within the tertiary-educated workforce moved by 15+ percentile ranks in several countries—consistent with substantial changes in selection into teaching. We then ask which policies and labor-market conditions (e.g., relative teacher wages, outside options for high-skilled women, and teacher status) are associated with these shifts. In a second step, we relate these country-level changes in teacher skills to changes in student achievement using rich PISA microdata in mathematics and reading. For identification, we exploit within-country variation across subjects and over time, testing whether students in countries where teachers gained in numeracy relative to literacy also improved more in math relative to reading. Data on subject-specific skills in PIAAC for the overall population and for detailed occupations enables a set of robustness checks and placebo tests that help separate changes in teacher skills from broader skill changes within countries. Understanding how and why teacher skills evolve internationally——and whether these changes translate into student achievement——matters for policies aimed at strengthening teacher quality and improving educational outcomes.

Keywords: Teacher quality, cognitive skills, student achievement, PIAAC, PISA

JEL Classification: I20, H40, and J20

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I Introduction

Skills and human capital are closely linked to later-life outcomes, particularly labor market success. Understanding how these skills develop—and why they sometimes erode—is therefore of central importance for economic policy. Beyond family background, formal education plays a key role in human capital formation, and within schools, teachers represent a particularly important lever for shaping student skills. Yet a basic question remains surprisingly open: are teachers getting smarter—or not?

The critical role of teachers in human capital production is well documented (Hanushek and Rivkin, 2012; Jackson et al., 2014). Teacher quality has large and persistent impacts on students' earnings and life outcomes (Chetty et al., 2014). Yet despite this evidence, we still know remarkably little about which specific teacher traits are responsible for these effects—teacher value-added measures are, in some sense, measures of ignorance. While conventional teacher characteristics such as educational attainment and teacher preparation characteristics exhibit inconsistent relationships with student achievement in cross-country comparisons (Hanushek and Woessmann, 2011), there is some evidence highlighting the importance of measured cognitive skills of teachers. In Hanushek et al. (2019), a one-standard-deviation increase in teacher cognitive skills across industrialized countries is associated with about 0.15 SD higher mathematics performance and about 0.09 SD higher reading performance, even after rich student-, family-, school-, and country-level controls. Moreover, the within-student (math–reading) design delivers very similar estimates, suggesting that the relationship is not driven by stable student heterogeneity or non-subject-specific country factors.[1]

However, existing evidence on the link between teacher skills and student performance has important limitations. Even in internationally comparable data, most analyses are essentially cross-sectional, leaving several fundamental questions open: How do teacher-skill distributions evolve over time? Do countries experience meaningful shifts in teachers' relative standing within the high-skilled workforce? Which labor-market conditions and policies are associated with these shifts? And do changes in teacher skills translate into changes in student achievement?

This paper tackles three related questions. First, how have the level and dispersion of teachers' cognitive skills in literacy and numeracy evolved over time across countries? Second, which institutional and labor-market conditions——such as relative teacher wages, outside options for high-skilled women, and teacher status——are associated with shifts in the teacher-skill distribution (Bacolod, 2007; Corcoran et al., 2004; Dolton et al., 2018;

[1] Complementary micro evidence using linked student–teacher test data from Sub-Saharan Africa finds that higher subject-specific teacher knowledge raises student performance in the corresponding subject using within-student across-subject variation (Bietenbeck et al., 2018).

Nagler et al., 2020)? Third, do changes in teacher skills translate into changes in student achievement and into the skill profiles of younger adult cohorts? In this draft, we document the evolution of teacher skills and lay out the empirical strategy for linking these changes to policies, labor markets, and student outcomes.

Answering the first question, we use newly available OECD data on teacher cognitive skills across countries *and* over time. Specifically, we draw on the Programme for the International Assessment of Adult Competencies (PIAAC), which covers 25 countries in two cycles of data collection over a 10-year span. On average across countries, teacher skills have changed only little over time. Median numeracy skills decreased by just one point (from 294 to 293), median literacy skills by two points (from 297 to 295). However, these aggregate patterns mask notable heterogeneity across countries. In the United States, for instance, median teacher numeracy rises from 284 to 292 and literacy from 301 to 304, narrowing the literacy–numeracy imbalance somewhat. In the United Kingdom, teachers improve in both domains (numeracy: from 289 to 300; literacy: from 299 to 304). Germany stands out for a meaningful increase in teacher literacy (+13 points), while changes in numeracy are more modest. At the same time, the cross-country heterogeneity is large: Lithuania experiences the steepest declines (30 in numeracy; 25 in literacy), while Japan and the Netherlands post strong gains in numeracy (+20 and +19).

Changes are equally striking when measured as teachers' percentile position within the tertiary-educated workforce—a direct proxy for selection into teaching. Finland's numeracy position drops by 17 percentile points, Chile improves by 11 points. Similarly, the Czech Republic's literacy position falls by 18 points, and France's rises by 16 points. Finally, these shifts in teacher skills occur against a backdrop of widespread student achievement declines, especially in mathematics. Taken together, these facts suggest that teacher skills are not a fixed country characteristic and motivate a systematic analysis of (i) what drives these shifts and (ii) whether they translate into student outcomes in a subject-specific way.

We complement the PIAAC-based teacher evidence with internationally comparable student achievement data from the Programme for International Student Assessment (PISA). We align PIAAC Cycle 1 (2012, 2015) with PISA waves 2009 and 2012, and PIAAC Cycle 2 (2022, 2023) with PISA waves 2018 and 2022, covering 25 countries and approximately 860,000 students. These combined data provide three distinct sources of variation: across countries, over time (between cycles), and across subjects (numeracy/mathematics versus literacy/reading).

The key innovation of our empirical approach is to bring temporal and subject-level variation into a literature that has largely relied on cross-sectional comparisons. We implement three complementary identification strategies, each designed to address different

sources of potential bias. First, our baseline panel specification exploits within-country changes in teacher skills over time, using country fixed effects and PISA-wave fixed effects to eliminate time-invariant country characteristics and common global shocks. Second, we implement a within-country, across subject, over time design, exploiting changes in the numeracy-literacy difference over time. Thus, we ask whether student in countries where teachers gained in numeracy relative to literacy also improved more in math relative to reading. Relative to a purely cross-sectional cross-subject design, adding the time dimension shifts identification from cross-country level differences to within-country changes, removing all time-invariant country factors that may jointly shape teacher skills and the math–reading achievement gap, including persistent subject-specific features such as long-standing curricular emphases or tracking regimes. The remaining identifying concern is time-varying, subject-specific shocks (e.g., math-only reforms). Third, we address these confounds by using subject-specific controls (such as instructional-time gaps and parental numeracy–literacy gaps) and placebo tests based on other occupations. Doing so helps us isolate genuine teacher effects from broader country-level skill evolution patterns.

We also examine whether changes in teacher cognitive skills are mirrored in the skill profiles of young adults observed in PIAAC, providing complementary evidence on whether shifts in teacher quality are reflected in broader patterns of human-capital formation beyond compulsory schooling.

This paper contributes to two main strands of research. First, we advance the literature on teacher skills and student outcomes, which has primarily relied on within-country evidence (Hanushek, 2002; Hanushek and Rivkin, 2012; Glewwe et al., 2013; Chetty et al., 2014; Jackson et al., 2014), by providing the first systematic cross-country analysis of how changes in teacher cognitive skills over time relate to changes in student achievement. Second, we contribute to research on teacher labor markets by investigating the determinants of these skill changes over time. Prior work has shown that women's outside options and teacher social status affect who enters teaching within individual countries (Corcoran et al., 2004; Bacolod, 2007), and that teachers entering the profession during recessions are significantly more effective in raising student test scores (Nagler et al., 2020). Cross-country evidence has documented that variations in teacher cognitive skills are associated with women's access to high-skill occupations and salary premiums for teachers (Dolton and Marcenaro-Gutierrez, 2011; Hanushek et al., 2019), and that higher teacher status correlates with better student performance (Dolton et al., 2018). We extend this evidence by examining whether changes in these labor market conditions drive changes in teacher quality within countries over time, bringing a temporal dimension to relationships previously documented only in cross-sectional comparisons or not at all.

The remainder of this paper is structured as follows. Section II reviews the related literature. Section III describes the data and documents the evolution of teacher cognitive skills and student performance. Section IV presents our estimation strategy. Section V reports the main results. Section VI investigates the determinants of teacher skill changes over time. Section VII concludes.

II Related Literature

A large literature examines the determinants of student achievement, with most evidence coming from within-country analyses. These studies document that educational outcomes reflect family background, school resources, and institutional features of education systems (Hanushek, 2002; Glewwe et al., 2013). Particularly important are differences in teacher quality. Research estimating teacher value-added to student learning reveals enormous variation in teacher effectiveness, far exceeding the contribution of other school inputs (Hanushek and Rivkin, 2012; Jackson et al., 2014). High-quality teachers generate lasting benefits: students exposed to more effective teachers earn substantially higher incomes in adulthood and experience improved life outcomes (Chetty et al., 2014). However, this within-country evidence—concentrated primarily in the United States—provides limited guidance for understanding cross-national differences in educational performance. While the findings of Hanushek et al. (2019) provide first systematic cross-country evidence on the positive relationship between teacher cognitive skills and student outcomes, the literature remains cross-sectional and has not examined how teacher quality and its relationship with student achievement evolve across countries in the long-run.

International comparisons of teacher quality have proven challenging, as commonly measured teacher characteristics—education levels, experience, and preparation programs—are inconsistently related to student achievement across countries (Hanushek and Woessmann, 2011). One notable exception is early-career experience: teachers in their first years of teaching show consistent improvement in effectiveness regarding student achievement with additional years on the job. Teacher cognitive skills offer a more promising avenue for understanding cross-country student achievement differences. Studies using individual-level teacher data demonstrate the relevance of teacher subject knowledge for student learning. Research in developing countries by Metzler and Woessmann (2012), and Bietenbeck et al. (2018) provides evidence that teachers' mastery of subject content predicts student achievement. However, measurement matters: Grönqvist and Vlachos (2016) employ a general IQ test rather than subject-specific assessments in Sweden and find negligible effects, underscoring the importance of domain-specific teacher knowledge measures. Additional evidence comes from teacher value-added studies demonstrating that teachers' own test performance is positively related to the learning gains they generate for their

students (Jackson and Bruegmann, 2009; Clotfelter et al., 2010). The first comprehensive international analysis comes from Hanushek et al. (2019), who use test data to construct country-level measures of teacher cognitive skills in numeracy and literacy for 31 countries. Their findings reveal substantial cross-national differences in teacher skills that strongly correlate with student performance. A one standard deviation increase in teacher cognitive skills is associated with 0.10–0.15 standard deviations higher student achievement. The relationship remains robust across different estimation strategies, including student fixed-effects models that exploit within-student variation between subjects. Nevertheless, this analysis—like the broader literature—relies exclusively on cross-sectional data and cannot determine whether the teacher skill–student performance relationship persists over time or how teacher quality evolves within countries across periods.

The composition and quality of the teaching workforce has changed substantially over time, with the most extensive evidence coming from the United States. Multiple studies document a downward trend in the cognitive skills of individuals entering teaching over recent decades (Corcoran et al., 2004; Bacolod, 2007; Murnane et al., 2009). Bacolod (2007) traces the decline in aptitude among young women choosing teaching careers from 1960 to 1990, attributing this pattern to deteriorating relative compensation for teachers. The erosion of teacher quality appears particularly pronounced among high-achieving individuals: Corcoran et al. (2004) demonstrate that the decline concentrated in the upper tail of the ability distribution, as expanding career opportunities for women outside education attracted talented individuals away from teaching. This body of work establishes a clear mechanism—changes in alternative employment prospects influence occupational sorting into teaching—but stops short of connecting observed shifts in teacher quality to student learning outcomes. Hanushek et al. (2019) examine cross-country variation in teacher cognitive skills in relation to the proportion of female teachers relative to all women in high-skill occupations. Countries where women have greater access to non-teaching professional careers exhibit lower teacher cognitive skills, consistent with increased competition for talented women. However, this cross-sectional evidence cannot address whether temporal changes in women's career opportunities or teacher compensation lead to corresponding shifts in teacher quality within countries over time, or whether the teacher skill-student performance relationship remains stable across countries and periods as labor markets change—questions we examine in this paper.

Beyond employment opportunities, teacher compensation structures represent a second important labor market mechanism influencing teacher quality. Within-country studies typically find weak associations between teacher salaries and measures of instructional effectiveness (Hanushek and Rivkin, 2006), though research exploiting regional relative wage variation identifies positive effects of relative teacher pay on school performance (Britton and Propper, 2016). Cross-country comparisons present a different picture:

analyses consistently document positive relationships between country-level teacher salary measures and student achievement (Lee and Barro, 2001; Woessmann, 2005; Dolton and Marcenaro-Gutierrez, 2011). This pattern suggests that aggregate compensation levels shape the quality composition of national teaching workforces, even when within-country salary variation fails to predict individual teacher effectiveness. Research on teacher status reinforces this interpretation, showing that countries where teaching commands greater social prestige exhibit stronger student outcomes (Dolton et al., 2018). Hanushek et al. (2019) advance this literature by estimating country-specific wage premiums for teachers—the earnings differential between teachers and comparable workers in other occupations, adjusting for gender, experience, and cognitive skills. Their analysis reveals that these premiums correlate positively with both teacher cognitive skills and student performance across countries, providing direct evidence that labor market compensation affects teacher quality. However, the cross-sectional nature of this analysis leaves open whether changes in teacher wage premiums within countries over time lead to corresponding changes in teacher quality and student outcomes—a question we address by comparing teacher compensation structures and their correlates across two distinct time periods.

III International Comparative Data

A The Evolution of Teacher Cognitive Skills

Our measures of teacher cognitive skills are constructed from the Programme for the International Assessment of Adult Competencies (PIAAC), a large-scale international assessment coordinated by the OECD. PIAAC Cycle 1 was conducted across three rounds of data collection (2011-2012, 2014-2015) and tested approximately 245,000 adults aged 16-65 in 39 countries and economies. PIAAC Cycle 2, conducted in 2022-2023, assessed approximately 155,000 adults across 31 countries and economies. The survey evaluates cognitive competencies in multiple domains, with numeracy and literacy being the core assessed skills relevant for our analysis. PIAAC measures both of the skill domains on a 500-point scale.

Following Hanushek et al. (2019), we define teachers as PIAAC respondents reporting a current four-digit occupation code corresponding to "primary school teacher," "secondary school teacher," or "other teacher" (which includes, for example, special education teachers and language teachers). We exclude university professors and vocational school teachers, as 15-year-old PISA students have not yet been instructed by these groups. We also exclude prekindergarten teachers, given uncertainty about their contribution to mathematics and reading instruction and because the role of early childhood educators varies substantially across institutional contexts. Since PIAAC does not identify the specific subject taught

by each teacher, we construct domain-general measures of teacher numeracy and literacy skills encompassing all teachers assessed within each country.

Our analysis focuses on 25 countries that participated in both PIAAC cycles and for which matched PISA student performance data are available across the corresponding time periods. This balanced panel structure enables us to examine the evolution of teacher cognitive skills over time while maintaining consistent cross-country comparisons. We follow Hanushek et al. (2019) in computing country-specific teacher skills as the median rather than the mean, as the median provides greater robustness to outliers—a particularly relevant consideration given the relatively modest teacher sample sizes in some countries. Individual observations are weighted using PIAAC final sample weights (inverse sampling probabilities) when constructing country-level aggregates.

Pooled patterns over time. On average across countries, teacher skills changed only modestly between the two PIAAC cycles (Table 1). In the pooled sample, median teacher numeracy decreases by one point (from 294 to 293) and median teacher literacy by two points (from 297 to 295). These aggregate patterns, however, mask substantial cross-country heterogeneity in both levels and changes.

Cross-country differences in levels. Tables 1 and 2 document the cross-sectional distribution of teacher cognitive skills in Cycle 1 and Cycle 2, respectively. In Cycle 1, Finland exhibits the highest median skills in both numeracy (317) and literacy (322), while Chile records the lowest medians (262 and 263). Several countries display pronounced domain-specific asymmetries: teachers in the United States, Canada, and New Zealand have considerably higher literacy than numeracy (domain differences of -17, -15, and -12 points), whereas Austria and Germany show the opposite pattern, with numeracy exceeding literacy by 8 and 7 points, respectively. The pooled Cycle 1 sample comprises 5,019 teachers across 25 countries (sample sizes ranging from 106 in Chile to 834 in Canada).

In Cycle 2, Japan has the highest median skills in both numeracy (331) and literacy (325), while Lithuania records the lowest medians (255 and 257). Domain-specific asymmetries remain substantial: New Zealand shows a large literacy advantage (numeracy–literacy difference of -24 points), while Singapore exhibits the largest numeracy advantage ($+15$ points). The Cycle 2 sample comprises 4,511 teachers across 25 countries (sample sizes ranging from 106 in the Netherlands to 365 in Israel).

Within-country changes in teacher skills. Figure 1 summarizes how teacher skills evolved between Cycle 1 and Cycle 2. Consistent with the pooled patterns above, average changes are small, but the dispersion of changes across countries is large. Several prominent

countries show noticeable gains: in the United States, median teacher numeracy increases from 284 to 292 and literacy from 301 to 304; in the United Kingdom, numeracy rises from 289 to 300 and literacy from 299 to 304; and Germany stands out for a meaningful increase in teacher literacy (+13 points), while changes in numeracy are more modest. At the other end of the distribution, Lithuania experiences the steepest declines (−30 points in numeracy and −25 in literacy), while Japan and the Netherlands post strong gains in numeracy (+20 and +19). Overall, Figure 1 highlights that teacher skills are not a fixed country characteristic, even over a relatively short time span.

Teacher selection: relative position within the tertiary-educated workforce. Absolute skill levels are informative, but they do not directly reveal whether teachers are drawn from the upper or lower part of each country's high-skilled workforce. Figure 2 therefore examines teachers' percentile position within the skill distribution of university-educated adults (excluding teachers). On average across countries, teachers' relative positions improve modestly between cycles (from the 46th to the 49th percentile in numeracy and from the 49th to the 52nd percentile in literacy). Yet, as with levels, these averages mask striking heterogeneity: changes range from −17 to +11 percentile points in numeracy and from −18 to +16 points in literacy. Finland's numeracy position drops by 17 percentile points, while Chile improves by 11 points. Similarly, the Czech Republic's literacy position falls by 18 points, whereas France's rises by 16 points. Several countries display consistent movements across both domains (e.g., Chile and Japan improve in both numeracy and literacy), while others show sharper shifts in one domain than the other. These results underscore that changes in teacher cognitive skills are closely tied to changes in selection into teaching relative to other tertiary-educated occupations.

Context: student performance trends. Finally, these changes in teacher skills occur against a backdrop of widespread student achievement declines, especially in mathematics. This motivates our subsequent analysis of (i) which policy and labor-market conditions are associated with shifts in teacher skills and (ii) whether countries where teachers gained in numeracy relative to literacy also improved more in mathematics relative to reading.

Scaling. For our econometric analysis we standardize teacher cognitive skills using global z-scoring across both PIAAC cycles for all countries in our sample, computed separately by domain. This pooled standardization yields a straightforward interpretation: a one-standard-deviation change in teacher skills corresponds to a change in student performance measured in standard deviations. Importantly, standardization must not be cycle-specific, as this would distort the interpretation of changes over time by mechanically imposing equal variances in each period. As a robustness check, we also report results using raw PIAAC score points.

Table 1: Teacher Cognitive Skills by Country (Cycle 1)

	Pooled	AUT	BEL	CAN	CHL	CZE	DEU	DNK	ESP
Numeracy	294	300	308	292	262	305	308	295	283
Literacy	297	292	303	307	263	300	301	288	290
Domain diff.	-3	8	5	-15	-1	5	7	7	-7
Num. percentile	68	69	68	67	81	73	72	56	75
Lit. percentile	70	70	71	72	79	77	74	60	80
Observations	5019	188	215	834	106	141	127	413	183

	EST	FIN	FRA	GBR	IRL	ISR	ITA	JPN	KOR
Numeracy	285	317	302	289	295	270	273	311	287
Literacy	294	322	296	299	300	281	279	319	296
Domain diff.	-9	-5	6	-10	-4	-12	-5	-8	-9
Num. percentile	60	73	80	65	75	57	67	70	72
Lit. percentile	69	74	77	67	74	62	73	67	74
Observations	188	221	163	310	180	250	124	147	217

	LTU	NLD	NOR	NZL	SGP	SVK	SWE	USA
Numeracy	285	304	302	297	303	294	306	284
Literacy	282	308	304	310	300	290	307	301
Domain diff.	3	-4	-2	-12	3	4	-1	-17
Num. percentile	66	63	65	64	72	66	62	70
Lit. percentile	64	67	68	71	76	60	65	71
Observations	133	197	279	198	193	133	147	132

Notes: Teacher cognitive skills are country-specific median cognitive skills of primary school teachers, secondary school teachers, and "other" teachers (including, for example, special education teachers and language languages). Because occupation in Finland is reported only at the two-digit level, teachers in this country include all "teaching professionals" (ISCO-08 code 23), that is, additionally include prekindergarten teachers and university professors. Percentile refers to the position of median cognitive skills of teachers in the cognitive skill distribution of all adults aged 25–65 excluding teachers. Individuals are weighted with PIAAC final sample weights. Observations refer to the number of teachers used to construct country-specific teacher skills. *Data source:* PIAAC Cycle 1 (2012, 2015).

Table 2: Teacher Cognitive Skills by Country (Cycle 2)

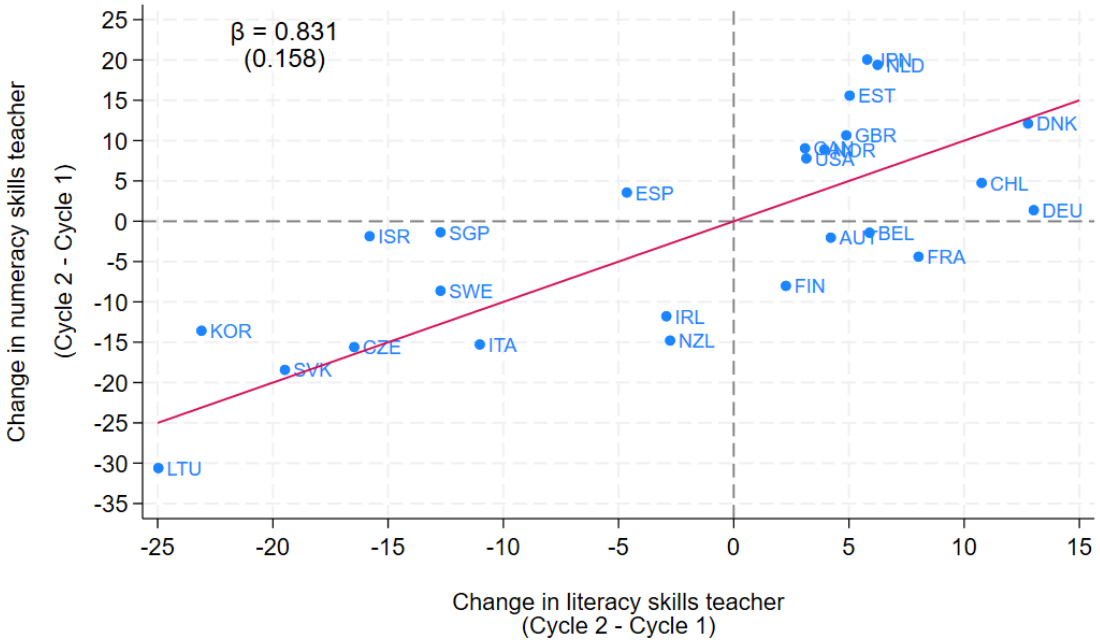
	Pooled	AUT	BEL	CAN	CHL	CZE	DEU	DNK	ESP
Numeracy	293	298	307	301	267	289	310	307	286
Literacy	295	297	309	310	274	283	314	301	285
Domain diff.	-2	2	-2	-9	-7	6	-5	6	1
Num. percentile	67	68	64	68	83	66	72	62	75
Lit. percentile	69	75	66	74	82	63	77	64	77
Observations	4511	180	194	301	133	181	140	222	224

	EST	FIN	FRA	GBR	IRL	ISR	ITA	JPN	KOR
Numeracy	300	309	297	300	284	268	258	331	273
Literacy	299	324	304	304	297	266	268	325	273
Domain diff.	2	-15	-7	-4	-13	2	-9	7	0
Num. percentile	59	56	76	69	70	62	62	77	69
Lit. percentile	63	61	81	74	74	62	66	74	70
Observations	221	179	174	166	168	365	107	170	211

	LTU	NLD	NOR	NZL	SGP	SVK	SWE	USA
Numeracy	255	323	311	283	302	276	297	292
Literacy	257	314	308	307	287	271	295	304
Domain diff.	-2	9	3	-24	15	5	3	-12
Num. percentile	63	71	61	66	62	62	53	70
Lit. percentile	66	70	63	74	66	60	51	72
Observations	108	106	177	132	144	245	133	130

Notes: Teacher cognitive skills are country-specific median cognitive skills of primary school teachers, secondary school teachers, and "other" teachers (including, for example, special education teachers and language teachers). Percentile refers to the position of median cognitive skills of teachers in the cognitive skill distribution of all adults aged 25–65 excluding teachers. Individuals are weighted with PIAAC final sample weights. Observations refer to the number of teachers used to construct country-specific teacher skills. *Data source:* PIAAC Cycle 2 (2022, 2023).

Figure 1: Changes in Teacher Cognitive Skills



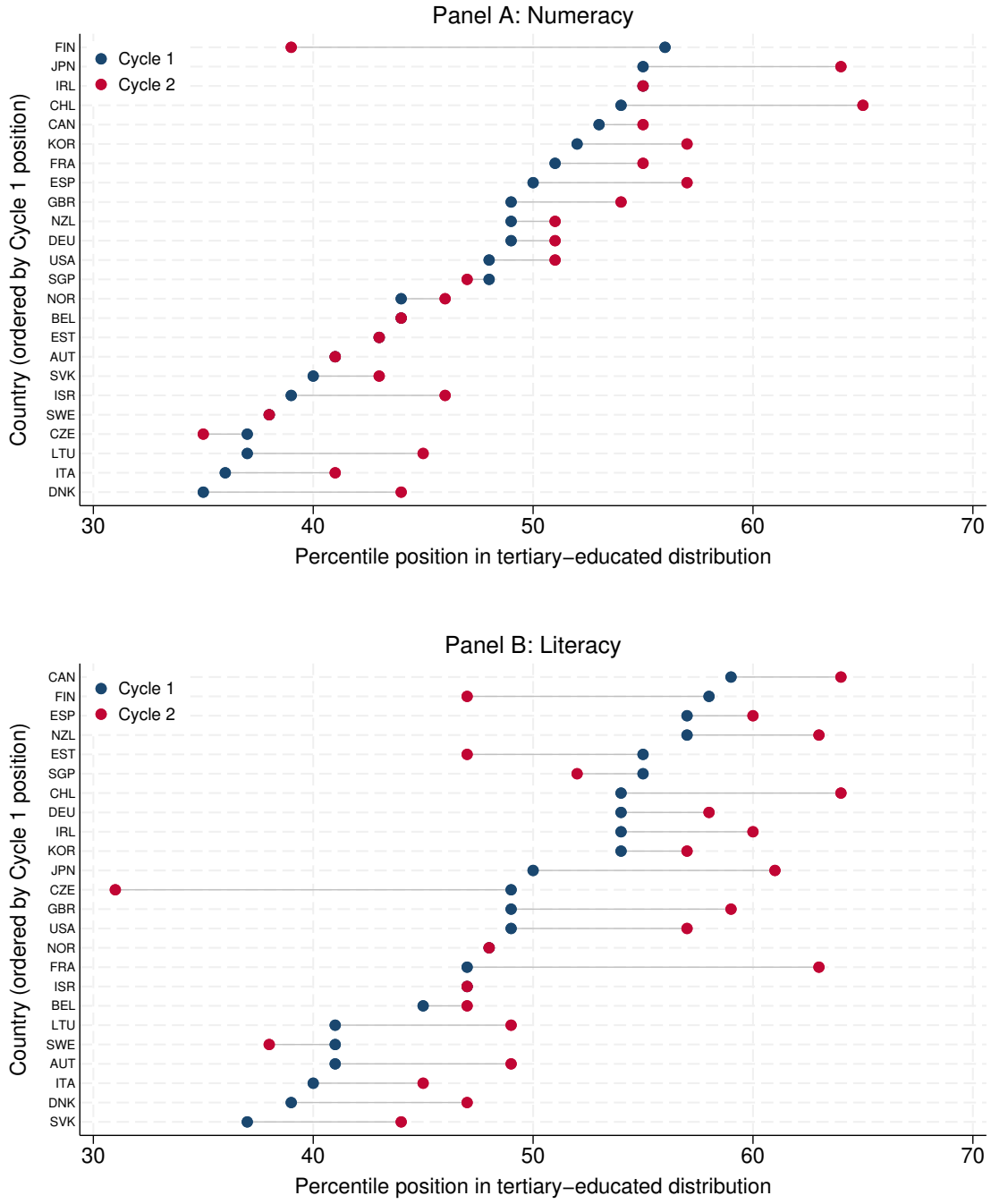
Notes: The figure shows changes in median teacher cognitive skills between Cycle 1 and Cycle 2 for 25 countries. The solid line represents the 45-degree line (y=x). Gray dashed lines mark zero change in each domain. *Data sources:* PIAAC Cycle 1 (2012, 2015) and PIAAC Cycle 2 (2022, 2023).

B The Evolution of Adult Cognitive Skills and the Teacher-Adult Skill Gap

Following Hanushek et al. (2019), we construct measures of country-specific adult cognitive skills using the median numeracy and literacy proficiency of all adults aged 25–65 assessed in PIAAC. Appendix Figure A1 and Figure A2 document the relationship between teacher cognitive skills and adult cognitive skills across both PIAAC cycles. The figures reveal substantial heterogeneity in the evolution of adult skills between Cycle 1 and Cycle 2. While median adult numeracy skills remained relatively stable across the 25-country sample (increasing by an average of 1.1 points), median adult literacy skills declined by 5.2 points on average. However, these aggregate patterns mask considerable cross-country variation: Finland experienced the largest improvements in both domains (+16.5 points in numeracy, +17.7 points in literacy), emerging as the global leader in adult skills in Cycle 2, while Lithuania suffered the most dramatic deterioration, declining by 19.4 points in numeracy and 28.5 points in literacy. The Nordic countries (Finland, Sweden) and Singapore demonstrate consistent skill improvements, whereas Eastern European countries (Lithuania, Slovakia, Czech Republic) and Korea exhibit substantial skill erosion in both competency areas.

Comparing these adult skill trajectories to teacher skill evolution reveals important

Figure 2: Change in Teacher Percentile Position in Tertiary-Educated Distribution



Notes: The figure shows changes in teachers' percentile position within the skill distribution of university-educated adults (excluding teachers) between Cycle 1 and Cycle 2. Panel A displays numeracy percentile changes, Panel B displays literacy percentile changes. Lines connect each country's position in Cycle 1 (navy) and Cycle 2 (cranberry). Countries are ordered by their Cycle 1 position. *Data sources:* PIAAC Cycle 1 (2012, 2015) and PIAAC Cycle 2 (2022, 2023).

dynamics in the relative positioning of teachers within their country's skill distribution. We define the teacher-adult skill gap as the difference between median teacher skills and median adult skills within each country and PIAAC cycle. Changes in this gap over time (Cycle 2 minus Cycle 1) reflect whether teachers' cognitive skills evolved differently from those of the broader adult population. Our analysis reveals a narrowing of the teacher-adult skill gap in numeracy (declining from 25.8 to 22.8 points on average) but a widening in literacy (increasing from 25.4 to 28.2 points). This differential pattern emerges because teacher numeracy skills declined more sharply than adult numeracy skills in several countries, while adult literacy skills deteriorated more rapidly than teacher literacy skills. Appendix Figure A3 and Figure A4 illustrate these dynamics by displaying changes in the teacher-adult skill gap for each country. The most pronounced gap narrowing occurred in Finland (-24.5 points in numeracy), Sweden (-21.7 points), and Singapore (-17.3 points), while Japan experienced the largest gap widening (+18.9 points in numeracy), driven primarily by substantial adult skill declines rather than teacher skill improvements. In literacy, Sweden exhibits the most dramatic gap narrowing (-22.7 points), whereas Austria (+18.1 points) and Chile (+12.9 points) show substantial gap widening, reflecting the divergent evolution of teacher and adult competencies across countries and domains.

C Parent Cognitive Skills

We also construct measures of parental cognitive skills by imputing numeracy and literacy competencies for PISA students' parents using PIAAC microdata (also also Hanushek et al., 2019). Since PISA does not assess parents directly, we employ a prediction-based approach. We first identify PIAAC respondents aged 35–59 who have children—representing adults who were 17–44 years old when the PISA cohort was born and thus constitute a plausible sample of potential PISA parents. For this subsample, we estimate country-specific prediction models that regress PIAAC numeracy and literacy scores on three observable characteristics available in both datasets: respondent gender, highest educational attainment (collapsed into three categories), and the number of books in the household (categorized into six groups).

We then apply the estimated coefficients to the corresponding characteristics of PISA students' mothers and fathers to predict individual-level parental skills. Our primary measure uses the maximum cognitive skill between mother and father as the parental skill proxy.

Importantly, parental cognitive skills exhibit variation both across subjects—as parents typically display differential strengths in numeracy versus literacy—and over time across PIAAC cycles, providing valuable within-student and temporal variation that strengthens our identification strategy.

Note: Full descriptive analysis of parent cognitive skills evolution across PIAAC Cycle 1 and Cycle 2 will be added upon availability of Restricted Use Files through OECD's Remote Code Execution service (expected March 2026).

D Student Performance

Student achievement data are drawn from the Programme for International Student Assessment (PISA), an international assessment coordinated by the OECD that evaluates the competencies of 15-year-old students in mathematics and reading. PISA employs a triennial testing cycle with nationally representative samples, targeting students at an age when most are nearing the completion of compulsory education.

Our analysis incorporates student performance data from four PISA waves spanning two distinct time periods. For Cycle 1, we use PISA 2009 and PISA 2012, which correspond to students primarily taught by the teacher cohorts assessed in PIAAC Cycle 1. For Cycle 2, we utilize PISA 2018 and PISA 2022, aligning with students instructed by teachers evaluated in PIAAC Cycle 2.

Mathematics performance declines across most countries between Cycle 1 and Cycle 2, with the majority of observations falling below the 45-degree reference line. Finland experiences the most dramatic decline, with scores dropping by more than 40 points—equivalent to approximately one full year of learning, given that typical annual progress corresponds to roughly 40 PISA points. Several countries maintain relatively stable performance levels across cycles, including Israel, Lithuania, and Japan. Strikingly, no country in our sample achieves substantial improvements in mathematics performance between the two periods, pointing to a widespread pattern of stagnation or decline in mathematical competencies among 15-year-old students in our sample.

Reading performance likewise declines across most countries between Cycle 1 and Cycle 2, following a similar distributional pattern as observed in mathematics. The Netherlands experiences the most pronounced decline, with scores dropping by approximately 50 points—representing more than one full year of learning loss. In contrast to the universal stagnation observed in mathematics, several countries achieve improvements in reading: Estonia, Ireland, and Singapore all demonstrate gains in competencies. Singapore maintains its position as the top-performing country while simultaneously improving further, whereas Chile remains the lowest-performing country in both cycles.

For the econometric analysis standardize student test scores using global z-scoring across both PISA waves and all countries in our sample, computed separately by subject. For each subject, standardization is performed using the mean and standard deviation calculated across all students from both PISA waves and all countries, weighted by PISA

student sampling weights with equal weight given to each wave to maintain country-equal weighting.

This pooled standardization ensures that both levels and changes in student performance are measured on a unified standard-deviation scale, making difference-in-difference estimates directly interpretable. For the cross-subject student fixed-effects design, we additionally standardize the mathematics-reading achievement gap itself using the mean and standard deviation of this gap computed across both waves and all countries. This ensures that the left-hand side of the gap specification captures changes in relative mathematics-versus-reading performance in standard-deviation units that are comparable over time.

IV Estimation Strategy

The key innovation of our empirical approach is to bring temporal and subject-level variation into a literature that has largely relied on cross-sectional comparisons. Our strategy combines three sources of variation: within-country changes over time, cross-subject differences between numeracy and literacy, and student-level microdata.

We construct teacher skill measures by country, PIAAC cycle, and domain using psychometrically linked scales. We implement long-difference designs comparing Cycle 2 to Cycle 1 to remove time-invariant country characteristics. We exploit cross-domain variation within countries to difference out country-wide shocks and reforms that affect mathematics and reading symmetrically. We rely on student-level PISA microdata to estimate effects with precision while identifying them from aggregated teacher skill changes. This combination yields a difference-in-differences-in-differences design—across countries, over time, and across subjects—that substantially reduces concerns about omitted variables at both the country and student level.

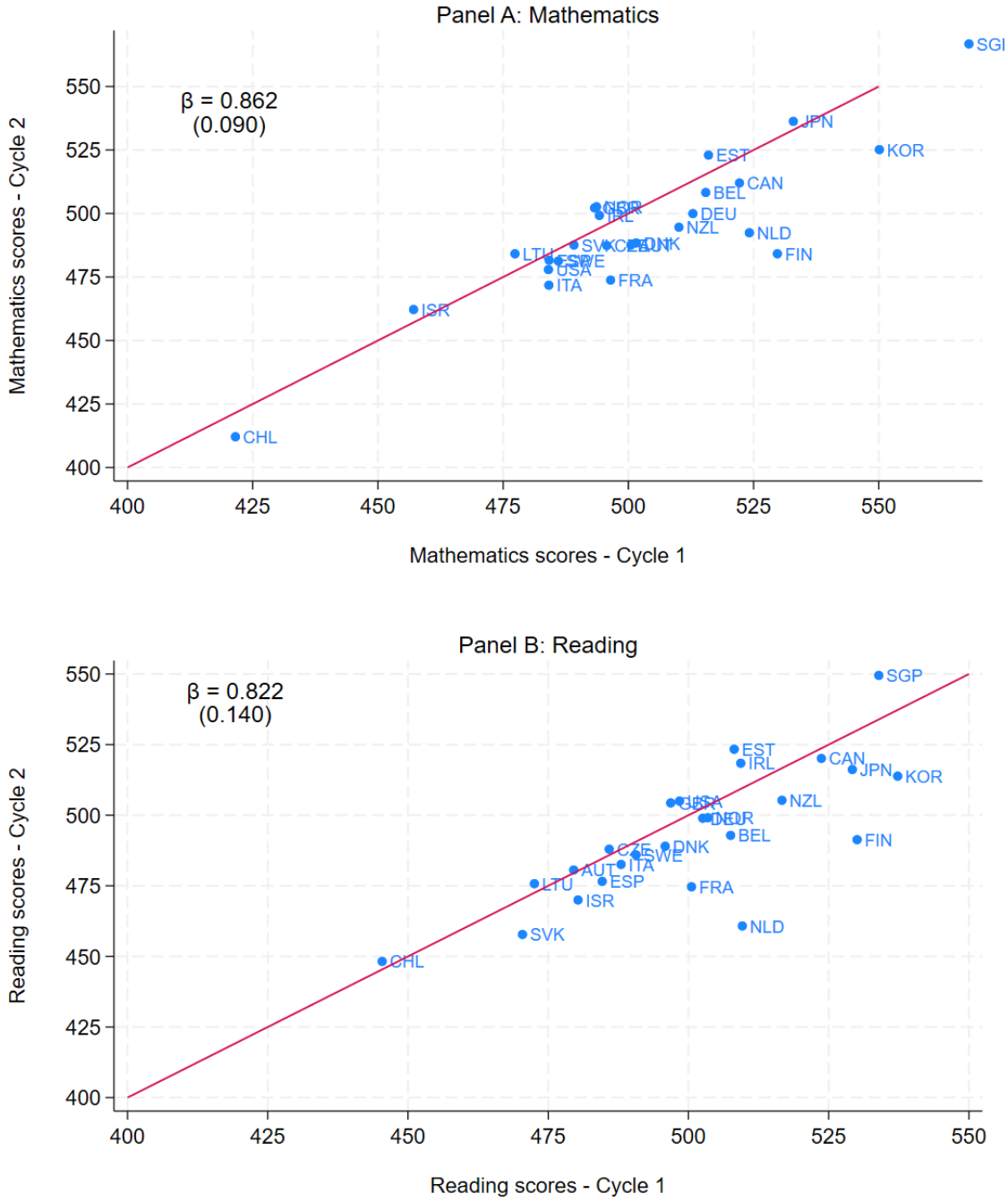
A Baseline Panel Specification

Our baseline approach exploits the full student-level variation in PISA microdata while identifying the effect of teacher cognitive skills exclusively from within-country changes over time. We stack student observations from multiple PISA waves linked to PIAAC Cycle 1 and Cycle 2 and estimate:

$$A_{icwk} = \beta\, T_{c,s(w),k} + X'_{icw}\gamma + \alpha_c + \lambda_w + \varepsilon_{icwk}, \tag{1}$$

where A_{icwk} denotes the standardized test score of student i in country c, PISA wave $w \in \{2009, 2012, 2018, 2022\}$, and subject $k \in \{\text{mathematics}, \text{reading}\}$. The variable

Figure 3: Student Performance Cycle 1 vs. Cycle 2



Notes: The figure shows country-level student performance in mathematics (Panel A) and reading (Panel B) across two time periods. Each point represents a country's median performance. The solid line represents the 45-degree line (y=x), indicating no change between cycles. Points above the line indicate performance improvements; points below indicate declines. *Data sources:* PISA 2009, 2012 ("Cycle 1") and PISA 2018, 2022 ("Cycle 2").

$T_{c,s(w),k}$ represents the cognitive skill level of teachers in country c and PIAAC cycle $s(w) \in \{1, 2\}$ corresponding to wave w, with teacher numeracy matched to mathematics and teacher literacy matched to reading. The vector X_{icw} contains control variables at the student, family, and school level (described below). Country fixed effects α_c absorb time-invariant country characteristics, while PISA-wave fixed effects λ_w capture global shocks and secular trends that affect achievement across countries in a given PISA wave.

In our baseline analysis, we estimate the model separately for each subject rather than pooling both subjects. In that case, we suppress the subject index k and interpret $T_{c,s(w),k}$ as the relevant teacher-domain measure for the respective subject.

The vector X_{icw} contains an extensive set of control variables at multiple levels. Student characteristics include age, gender, migrant status (first-generation or second-generation), and language spoken at home. Parent characteristics comprise parents' educational degree, number of books at home, and occupation. School characteristics include school location, number of students per school, three autonomy measures, as well as weekly instructional time in math classes or language classes. Country characteristics include expenditures per student and school starting age. All regressions include indicators for imputation flags and controls for the exact PISA wave.

Identification in this panel specification relies on within-country changes in teacher cognitive skills over time. By including country fixed effects, we difference out all time-invariant country-level factors. The coefficient β is identified from changes in teacher cognitive skills between PIAAC cycles and corresponding changes in student achievement across PISA waves, conditional on controls and global wave effects.

We implement this specification by stacking PISA student microdata from waves closest to PIAAC Cycle 1 (PISA 2009 and 2012) and PIAAC Cycle 2 (PISA 2018 and 2022), merging country×cycle×subject teacher cognitive skill measures from PIAAC to each student observation. Because the key regressor varies at the country×cycle×subject level, we cluster standard errors at the country level. Given the small number of clusters (25 countries), we also employ wild cluster bootstrap procedures for inference as robustness.

While country fixed effects eliminate all time-invariant confounders, the baseline specification remains vulnerable to bias from time-varying country-level factors that correlate with both changes in teacher cognitive skills and changes in student performance. To mitigate such concerns—especially for shocks that affect mathematics and reading similarly—we employ an alternative identification strategy that exploits differential variation across subjects within students and within countries over time.

B Cross-Subject Student Fixed-Effects Design

To address the concern that time-varying country-level factors may confound the relationship between teacher skills and student performance, we employ an alternative identification strategy that exploits within-student variation across subjects. This approach extends the cross-subject design used by Hanushek et al. (2019) by adding an explicit time dimension. We examine whether changes in the gap between teacher numeracy and literacy skills within countries correspond to changes in the gap between student mathematics and reading performance.

Our specification takes the form:

$$(A_{icw,\text{math}} - A_{icw,\text{read}}) = \beta\,(T_{c,s(w),\text{num}} - T_{c,s(w),\text{lit}}) + X_{icw}^{gap\prime}\gamma + \alpha_c + \lambda_w + u_{icw}, \qquad (2)$$

where the left-hand side represents the within-student difference in standardized test scores between mathematics and reading for student i in country c and PISA wave w. The right-hand side includes the corresponding difference between teacher numeracy and literacy skills in the same country and PIAAC cycle, along with country fixed effects α_c and PISA-wave fixed effects λ_w.

The vector X_{icw}^{gap} includes time-varying controls that may differentially influence mathematics versus reading. Key controls include (i) a student-level proxy for the parental numeracy–literacy gap (constructed following Hanushek et al. (2019)) and (ii) country×wave measures of the gap in weekly instructional time between mathematics and reading/language classes. These controls account for subject-specific changes in family inputs and educational resource allocation that could confound the relationship between teacher skill gaps and student performance gaps.

This specification differences within students/countries across subjects and over time. By taking within-student differences across subjects, the specification differences out all student-specific characteristics that affect mathematics and reading performance similarly, such as general ability, motivation, test-taking skills, and broad family background factors. Country fixed effects eliminate all time-invariant country-level confounders—including persistent subject-specific differences (e.g., systematically math-oriented curricula). PISA-wave fixed effects eliminate common shifts in the math–reading gap (e.g., relative scaling or difficulty changes) across countries.

An additional advantage of the gap specification is that it differences out time-varying country-level factors that affect mathematics and reading equally (e.g., broad changes in educational investments or cohort-wide shifts in skills). However, time-varying factors that affect mathematics and reading differentially (e.g., math-only reforms) remain potential confounders, motivating the inclusion of X_{icw}^{gap} and the robustness checks described below.

Measurement error in teacher skills. Teacher skill aggregates are estimated from finite PIAAC samples and are particularly noisy in changes, which can attenuate estimates toward zero. As a robustness check, we apply empirical-Bayes shrinkage to the country×cycle×domain teacher-skill estimates prior to constructing gaps and long differences.

C Teacher Skills and Adult Skill Formation

Beyond student achievement, we investigate whether changes in teacher quality are reflected in the skills of young adults—cohorts most plausibly proximate to their schooling period. We compute median cognitive skills for individuals aged 25–34 in each country c and PIAAC cycle t, separately for numeracy and literacy, denoted $S_{c,\text{young,num},t}$ and $S_{c,\text{young,lit},t}$. We then estimate the long-difference relationship:

$$\Delta(S_{c,\text{young,num}} - S_{c,\text{young,lit}}) = \rho\,\Delta(T_{c,\text{num}} - T_{c,\text{lit}}) + \omega'\Delta X_c + e_c, \tag{3}$$

where $\Delta(\cdot)$ denotes the change from PIAAC Cycle 1 to Cycle 2. The vector ΔX_c captures country-level compositional changes relevant for young cohorts (e.g., changes in migration composition or educational attainment shares).

The coefficient ρ captures the medium-run association between changes in teacher cognitive skills and changes in the relative numeracy–literacy skill profile of young adults. By focusing on young adults and examining changes in skill gaps rather than levels, this specification differences out permanent country characteristics and country-wide shocks that affect both domains similarly. Given the limited number of countries, we interpret these estimates as descriptive and complementary evidence.

V Teacher Cognitive Skills and Student Performance over Time

Note: Results will be available until April 2026.

A Baseline Panel Results

Baseline panel results will be added here.

B Cross-Subject Student Fixed-Effects Results

Student FE results will be added here.

C Robustness Checks

We will conduct several robustness checks to validate the main findings, though the following list is not exhaustive.

First, we will examine sensitivity to alternative PISA wave pairings with PIAAC cycles. Our baseline specification uses multiple PISA waves per cycle (2009/2012 for Cycle 1; 2018/2022 for Cycle 2), but alternative specifications using only PISA 2012 and 2022 or other wave combinations test whether results are robust to different temporal alignments between teacher assessments and student outcomes.

Second, we will verify results using mean rather than median skill measures for teachers and adults. While the median provides robustness to outliers in relatively small teacher samples, mean-based measures offer an alternative aggregation approach that weights all observations equally.

Third, we will conduct leave-one-out analysis by sequentially excluding each country from the sample. This ensures that results are not driven by individual countries with particularly large changes in teacher skills or unusual patterns in student performance evolution.

Fourth, for the adult skill formation analysis, we will test alternative age bands (e.g., 25–29 years, 30–34 years) to examine whether results are sensitive to the definition of young adults most plausibly exposed to changes in teacher quality during their schooling period.

Additional robustness checks will be conducted as the analysis progresses.

D Placebo Tests and Falsification Checks

To provide evidence that the estimated relationship between teacher skill gaps and student performance gaps reflects a genuine teacher effect rather than spurious correlation with broader country-level trends, we will conduct placebo tests using cognitive skill gaps from other occupations. This represents one among several planned falsification checks.

Specifically, we will replace the teacher numeracy-literacy gap with corresponding domain gaps for other professional occupations (e.g., managers, other professional workers) in the gap-over-time model. If the estimated effects are driven by teacher-specific human capital rather than general country-level skill evolution patterns, these alternative occupational skill gaps should show no systematic relationship with changes in student achievement gaps. A finding of null effects for non-teaching occupations would strengthen the interpretation that teacher cognitive skills have a causal impact on student learning outcomes, as these other professional groups have no direct instructional role in secondary education.

Additional placebo tests and falsification checks will be conducted as the analysis progresses.

Note: Placebo tests using occupation-specific skill gaps require access to PIAAC Restricted Use Files through OECD's Remote Code Execution service (expected March 2026).

VI Determinants of Teacher Cognitive Skills over Time

Finally, we investigate the factors associated with changes in teacher quality within countries. Understanding what correlates with teacher skill levels rising or falling over time is important for informing policies to strengthen the teaching workforce. We employ a first-difference approach that relates changes in teacher skills between PIAAC cycles to changes in country-level conditions affecting teacher labor markets.

Our empirical specification takes the form:

$$\Delta T_{c,s} = \alpha + \beta' \Delta X_c + \gamma' \Delta Z_{c,s} + u_{c,s}, \tag{4}$$

where $T_{c,s}$ denotes the teacher skill statistic in country c and domain $s \in \{\text{numeracy}, \text{literacy}\}$. The teacher skill statistic can capture either central tendency (e.g., the median or mean) or dispersion (e.g., the standard deviation, interquartile range, or selected percentiles of the teacher skill distribution). The operator Δ denotes the change between Cycle 1 (2011–2012/2014–2015) and PIAAC Cycle 2 (2022–2023). The unit of observation is thus a country×domain cell.

The vector ΔX_c captures country-wide, time-varying factors that may shift teacher labor supply, demand, and selection. These include changes in relative teacher pay (the compensation of teachers relative to other occupations), overall labor-market tightness (general employment conditions that affect occupational choices), women's access to high-skill employment opportunities outside teaching (e.g., the share of professional occupations available to female workers), and changes in teacher status or prestige indices (Dolton et al., 2018).

The vector $\Delta Z_{c,s}$ contains domain-specific, time-varying factors that plausibly affect the teacher pipeline differentially in numeracy versus literacy. We consider factors such as changes in labor-market returns to numeracy versus literacy skills (differential wage premiums for quantitative versus verbal abilities in non-teaching occupations) and domain-specific teacher shortages (e.g., shortages of STEM/mathematics teachers relative to language teachers).

A key advantage of this first-difference specification is that it differences out all time-invariant country characteristics—including persistent educational culture, long-run institutions, and stable features of national education systems—as well as all time-invariant domain-by-country factors, such as a country's stable comparative advantage in mathematics versus reading instruction. Identification therefore relies on within-country changes in labor-market conditions and how these changes correlate with observed changes in teacher cognitive skills.[2] We focus on two key mechanisms that theory and prior research suggest are particularly important for teacher selection: women's evolving access to alternative professional opportunities and changes in the wage premiums paid to teachers relative to comparable workers in other occupations.

A Alternative Professional Opportunities for Women

Analysis of female labor market opportunities and the associations for teacher labor markets will be added here.

B Evolution of Wage Premiums and Returns to Skills for Teachers over Time

This section will present complementary evidence on teacher labor market dynamics, including the evolution of wage premiums for the teaching profession relative to other occupations and whether wage returns to cognitive skills vary across teacher age cohorts or time periods. These analyses provide context for understanding teacher selection patterns and the changing quality of teacher human capital over time.

VII Conclusions

Understanding how teacher cognitive skills evolve over time—and whether such shifts translate into student outcomes—is central for education policy. While prior research shows that teachers' cognitive skills are strongly related to student achievement, much of the evidence relies on cross-sectional comparisons and therefore cannot speak directly to how changes in teacher skills within a country map into changes in student performance.

This paper takes a first step toward filling this gap by documenting the evolution of teacher numeracy and literacy skills across 25 countries between PIAAC Cycles 1 and 2 and by outlining an empirical strategy to relate these changes to student achievement trends. A key descriptive finding is that average movements are small, but cross-country heterogeneity is substantial. In the pooled sample, median teacher numeracy declines

[2] Given the limited number of countries and the observational nature of the data, we interpret these estimates as descriptive associations.

by only one point and median literacy by two points, yet several countries experience declines on the order of one standard deviation while others exhibit sizable improvements. Importantly, changes are not limited to absolute skill levels: teachers' relative position within the tertiary-educated workforce—a proxy for selection into teaching—also shifts markedly, with movements exceeding 15 percentile points in multiple countries. These dynamics unfold against a backdrop of widespread declines in student achievement, particularly in mathematics.

In ongoing work, we relate country-level changes in teacher skills to changes in student achievement using rich PISA microdata in mathematics and reading. Our preferred design is a within-country, across-subject, over-time "gaps" approach: we test whether students in countries where teachers gained in numeracy relative to literacy also improved more in mathematics relative to reading. This design strengthens identification relative to purely cross-sectional gaps models by shifting identification from cross-country level differences to within-country changes, thereby removing time-invariant country factors—including persistent subject-specific features such as long-standing curricular emphases or tracking regimes. Remaining concerns are time-varying, subject-specific shocks (e.g., math-only reforms), which we address using subject-specific controls (such as instructional-time gaps and parental numeracy–literacy gaps) and placebo tests based on other occupations.

Finally, we study which labor-market and policy conditions are associated with shifts in teacher skill distributions over time. Using a first-difference framework, we relate changes in teacher skills to changes in relative teacher pay, women's access to high-skill occupations outside teaching, and indicators of teacher status. Taken together, the evidence highlights that teacher skills are not a fixed country characteristic and motivates a policy-relevant research agenda on how teacher labor markets shape the skill composition of the teaching workforce—and whether these shifts translate into student learning.

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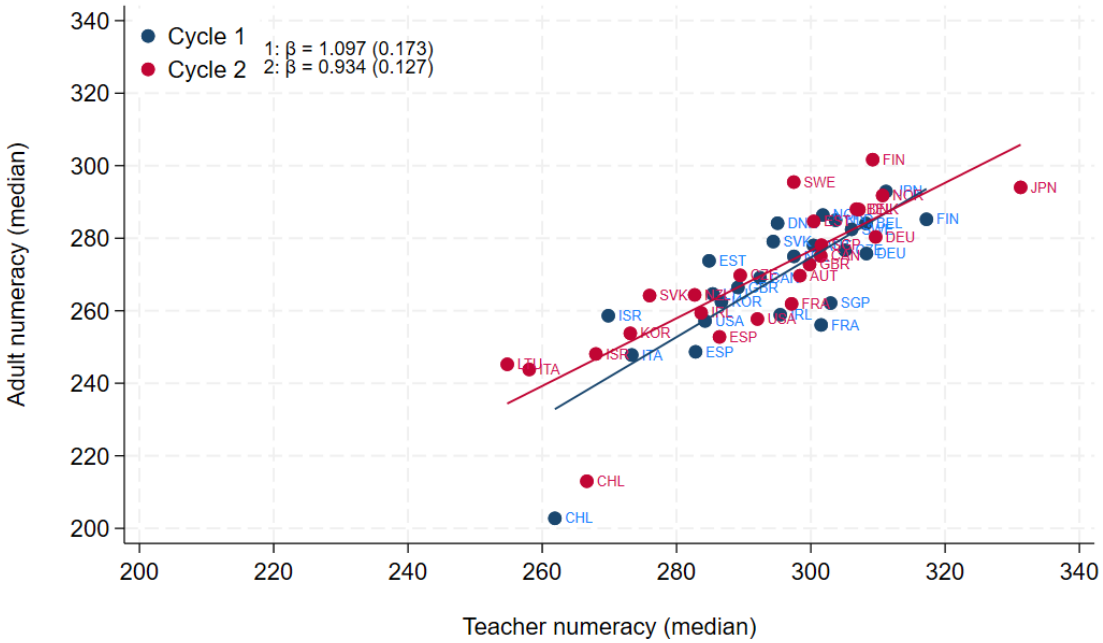
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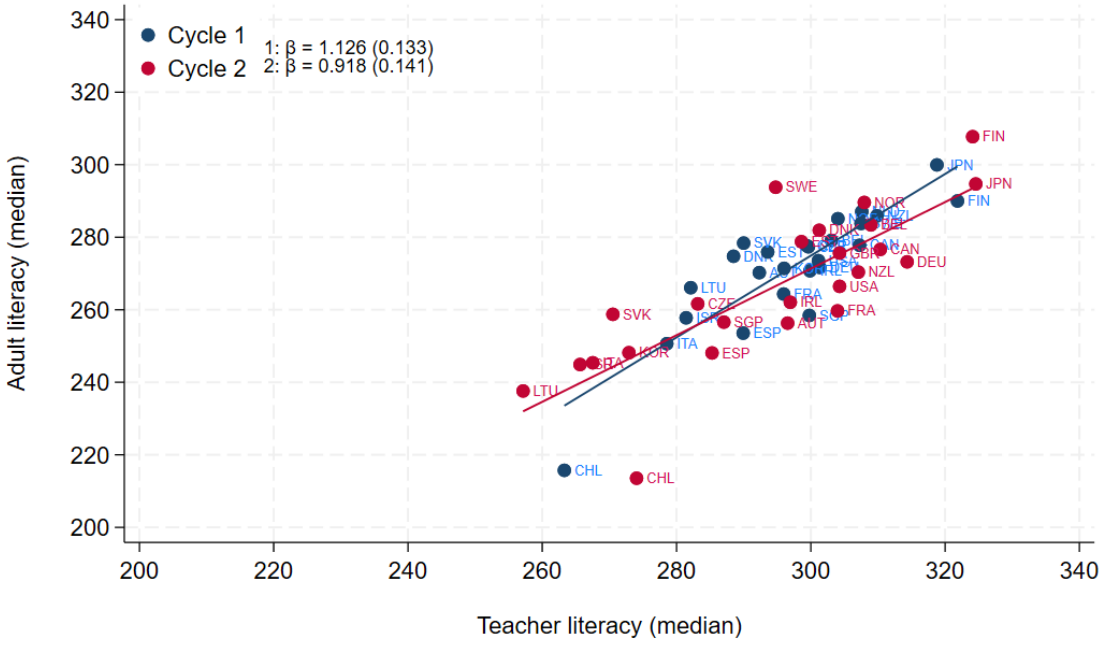
A Supplementary Figures

Figure A1: Teacher Cognitive Skills vs. Adult Cognitive Skills: Numeracy



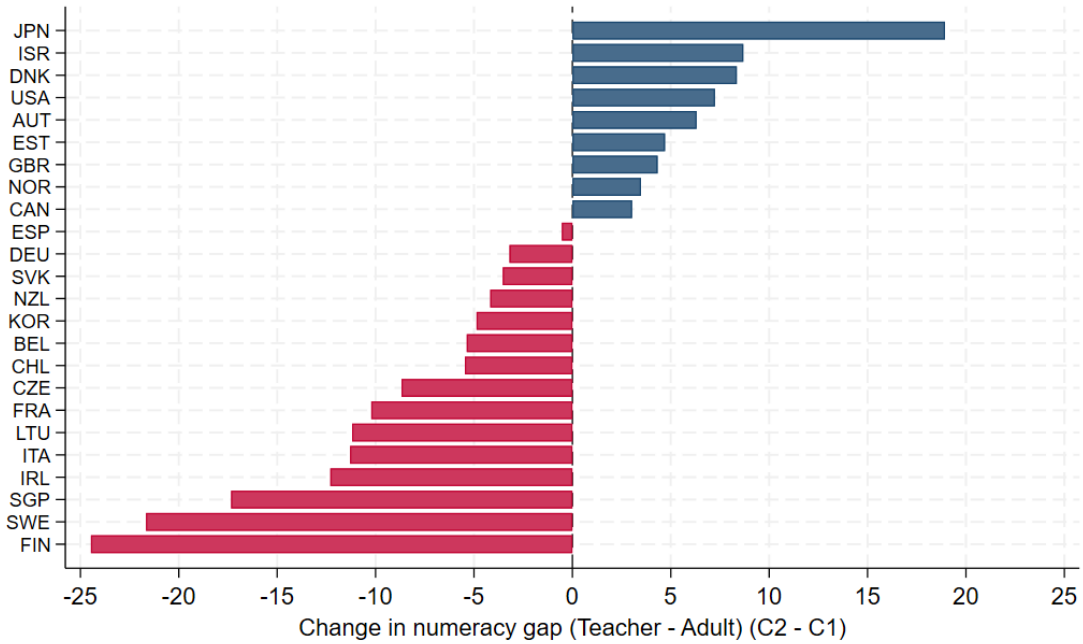
Data sources: PIAAC Cycle 1 (2012, 2015) and PIAAC Cycle 2 (2022, 2023).
Notes: The figure displays the relationship between median teacher numeracy skills and median adult numeracy skills for 25 countries across two PIAAC cycles. Adult skills in Cycle 2 are computed from Public Use Files (Netherlands excluded due to data availability). The fitted lines show the bivariate relationship between teacher and adult skills for each cycle separately.

Figure A2: Teacher Cognitive Skills vs. Adult Cognitive Skills: Literacy



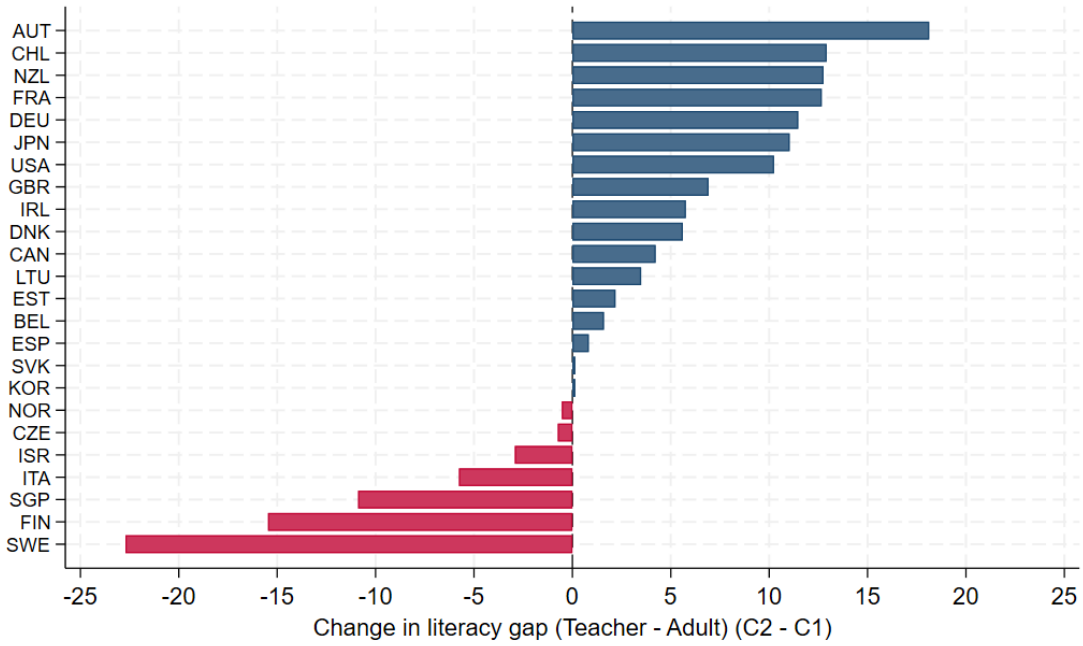
Data sources: PIAAC Cycle 1 (2012, 2015) and PIAAC Cycle 2 (2022, 2023).
Notes: The figure displays the relationship between median teacher literacy skills and median adult literacy skills for 25 countries across two PIAAC cycles. Adult skills in Cycle 2 are computed from Public Use Files (Netherlands excluded due to data availability). The fitted lines show the bivariate relationship between teacher and adult skills for each cycle separately.

Figure A3: Changes in Teacher-Adult Skill Gap: Numeracy



Data sources: PIAAC Cycle 1 (2012, 2015) and PIAAC Cycle 2 (2022, 2023).
Notes: The figure displays changes in the gap between median teacher numeracy skills and median adult numeracy skills between Cycle 1 and Cycle 2. Positive values indicate that teacher skills increased more (or decreased less) than adult skills. Negative values indicate that teacher skills increased less (or decreased more) than adult skills. Adult skills in Cycle 2 are computed from Public Use Files (Netherlands excluded due to data availability).

Figure A4: Changes in Teacher-Adult Skill Gap: Literacy



Data sources: PIAAC Cycle 1 (2012, 2015) and PIAAC Cycle 2 (2022, 2023).
Notes: The figure displays changes in the gap between median teacher literacy skills and median adult literacy skills between Cycle 1 and Cycle 2. Positive values indicate that teacher skills increased more (or decreased less) than adult skills. Negative values indicate that teacher skills increased less (or decreased more) than adult skills. Adult skills in Cycle 2 are computed from Public Use Files (Netherlands excluded due to data availability).