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Research paper

Trends in reading teacher shortage: Using 20 years of evidence from PIRLS

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ABSTRACT

Teacher shortages have emerged as a critical global issue, directly impacting international efforts to ensure equitable access to quality education. This study provides a comprehensive, longitudinal analysis of reading teacher shortages using data from the Progress in International Reading Literacy Study (PIRLS) spanning 2001 to 2021. Drawing on principal-reported data across five survey cycles, we investigate trends in teacher shortages over two decades, their distribution across socioeconomic contexts, and disparities between rural and urban schools. Our findings reveal that, while global shortage rates have remained relatively stable, significant variation exists at the country level. This includes divergent trends in shortage rates and persistent inequalities in their distribution, particularly across schools serving low and high socioeconomic populations and those in rural versus urban areas. These results underscore the critical need for country-specific, policy-driven interventions to address teacher shortages and mitigate inequalities. Furthermore, the study identifies countries that have successfully reduced shortages or inequalities, offering a foundation for future research to examine effective policy frameworks. By highlighting the complexities of teacher shortages at global, national, and contextual levels, this study advances the discourse on education equity and contributes actionable insights for addressing this pressing issue.

1. Introduction

The United Nations' Sustainable Development Goal 4 aims to ensure equitable access to quality primary and secondary education by 2030, including eliminating wealth-based disparities (UNESCO, 2024). Meeting this goal requires addressing the global teacher shortfall—currently estimated at 44 million educators, roughly half the existing workforce and lower than the 69 million projected in 2016—and tackling persistent literacy gaps, with 750 million people not proficient in reading and writing, skills largely developed in primary schooling (UNESCO, 2019). In this context, literacy is a critical priority area, and "teacher shortages" encompass both insufficient numbers of teachers and insufficient numbers of teachers qualified to teach their subjects (Cobbold, 2015; Erceg et al., 2022; Fuentes & Bloom, 2023). Accordingly, a key SDG 4 target is not only to expand the teaching workforce but also to increase the share of qualified teachers to deliver high-quality instruction.

A focus on high quality education includes high quality teachers who are equipped with the knowledge and skills to teach their students and assess and meet their needs. Studies in the United States have found a correlation between qualified, effective teachers and academic gains for primary school students (Haycock, 1998; Rivkin et al., 2005). Despite ranging certification standards for teachers internationally, qualified teachers must be able to not only manage and teach a classroom but demonstrate knowledge of how students learn in the specific subject that they are teaching. One common approach to measuring the quality of education in a country is through student achievement. However, other perspectives suggest that countries can also evaluate their success and learn from each other by looking at the broader contexts of their education systems (Boeren, 2019). This perspective views education as a common responsibility, not just that of an individual student or teacher, but also including policy makers in the shared responsibility of ensuring equitable and universal education access.

The distribution of teacher demand is not equal, with about one in three, 15 million, teacher vacancies located in sub-Saharan Africa (UNESCO, 2019). Northern Africa and Western Asia make up another 4.3 million of the demanded teachers, South East Asia another 4.5 million, Europe and North America have a demand of 4.8 million more

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teachers, Latin America and the Caribbean have a shortage of 3.2 million teachers, and Oceania and Central Asia share a combined need of 1 million teachers. The unequal distribution of need is an indication of differing contexts across the world. The challenges countries face in their path to meeting Goal 4 vary. Some countries do not have sufficient methods for attracting qualified candidates to the teaching profession, others face significant issues with retaining their teachers in the workforce, and rapidly rising populations can make it difficult for countries to develop and attract a sufficiently sized teacher workforce (UNESCO, 2019).

To address the multifaceted and globally uneven challenge of teacher shortages, we analyze five PIRLS cycles (2001–2021) covering 65 education systems across world regions—Europe (35), Asia (18), the Americas (8), Africa (2), and Oceania (2)—including both national and sub-national systems (e.g., England, Scotland, Northern Ireland; Canadian provinces; Hong Kong SAR; Chinese Taipei; Macao SAR; Abu Dhabi and Dubai in the UAE). By examining teacher shortages through the lenses of socioeconomic disparity and rural-urban divides, this research provides a granular understanding of how teacher distribution varies across contexts and over time. The findings not only highlight critical inequalities but also identify countries that have successfully mitigated shortages and inequalities, offering valuable lessons for policy development. This investigation situates teacher shortages within the broader framework of Sustainable Development Goal 4, contributing actionable insights for both national and global stakeholders working to achieve equitable, high-quality education for all. Through this lens, the study advances both theoretical and practical discourses, emphasizing the urgent need for targeted interventions and collaborative policy frameworks to address persistent inequalities in teacher distribution and educational opportunity.

1.1. Social reproduction

Pierre Bourdieu's theory of social reproduction explains that unequal distribution of resources fosters social inequality, allowing it to continuously reproduce itself over generations (Bourdieu, 1973). Education systems are oftentimes a tool of social reproduction, benefiting the already dominant culture, typically students from high socioeconomic backgrounds. The culture that is oftentimes most prominent in education is the dominant one, which benefits those who are already in it while disadvantaging students with other cultures and backgrounds. This reproduces existing hierarchies, making education more a means of reinforcing the dominant culture than meeting the needs of students with less social and cultural capital. Bourdieu's social reproduction theory understands that school systems are designed to exclude students from lower socioeconomic backgrounds and cultural minorities by neglecting them (Nash, 1990). When schools do not cater to the needs of students from non-dominant cultures, or acknowledge the differing contexts of students' learning, they continuously better serve students from the dominant culture (see also Calarco, 2018; Lareau, 2011; Reay, 2018).

In education systems where schools lacking the resources students need to succeed are more concentrated in low socioeconomic status (SES) communities, inequalities are reproduced. This is demonstrated in the United States, where areas with at least 10 % teacher vacancies are nearly twice as common in low SES neighborhoods as they are in high SES neighborhoods (Schmitt & deCourcy, 2022). Furthermore, students from lower socioeconomic backgrounds tend to have teachers with lower qualifications, again demonstrating social reproduction as lower income students receive lower quality education in the classroom and have lower academic outcomes (Darling-Hammond, 2000). Similarly, more affluent schools in England have more teachers with degrees relevant to their subject (Sibieta, 2018). Therefore, understanding the role of teacher shortages in perpetuating educational inequalities is critical, as this phenomenon exemplifies how systemic disparities are embedded within schools. The goal is not only to document these disparities but to provide actionable insights that inform equitable policy interventions, ensuring education systems serve as mechanisms for social mobility rather than tools for reinforcing existing inequalities.

1.2. National research on teacher shortages

While general teacher shortages are widely studied, a focus on teachers with a specialization in reading is needed to understand teacher shortages in the context of literacy development. Existing research on teacher shortages often focuses on the widespread teacher shortage across disciplines, or more specifically on STEM shortages. Existing studies primarily examine individual countries and the trends and causes of their teacher shortages independently.

In the United States, there was both a shortage of about 112,000 teachers in 2017 and another 109,000 teachers who were not properly certified for their jobs (Sutcher et al., 2019). In the United States, teacher shortages are unevenly distributed with high-poverty schools having a greater proportion of teachers without credentials, minimal experience, or no degree in the subject they teach (García & Weiss, 2020). Studies on solutions to the teacher shortage in the United States include the Talent Transfer Initiative, an effort to combat a shortage of quality teachers in low performing schools (Glazerman et al., 2013). A study of the program, which gave bonuses to high-ranked teachers who moved to low-performing schools for two years, found that financial incentives improved movement and retention for the two-year payment program but did not produce significant increases in retention afterwards.

A 2022 study in Sweden found that the low supply of teachers is contributing to their teacher shortage (Lindqvist et al., 2022). The annual cohort of teacher education program graduates made up 6 % of the unfulfilled demand. Only 65 % of people who enroll in these programs complete them and enter the teaching profession. In contrast, Singapore experiences less issues with teacher shortages. This is because of their relatively low teacher attrition rate (Ng et al., 2018). One factor contributing to better retention in Singapore is their teacher education strategy that includes mandating spending time working in a school before one enters a teacher education program. These experiences help prospective teachers understand what the career is like, allowing them to determine if the path is right for them.

Research on subject-specific shortages oftentimes evaluates the rising need for STEM teachers. A study on teacher shortages in New Zealand focused specifically on technology teachers, where there is an increasing focus in educating students (Reinsfield & Lee, 2022). To meet the rising demand for technology courses, 68 % of schools reported using unspecialized teachers for the courses. Studies of other countries also concentrate on STEM teacher shortages in the United States (Fuentes & Bloom, 2023; Toh et al., 2006), England (Hillier et al., 2013), Croatia (Erceg et al., 2022), and across the European Union (Davydovskaia et al., 2021).

Changing demand is another facet of teacher shortages that has been explored on a national level. An Ugandan study identified a growing demand for teachers as secondary education became universal in 2011 (Arinaitwe & Corbett, 2022). Specifically, rural areas cannot efficiently attract or retain their teachers for reasons including conflict and safety, geographic accessibility, disease risk, and less access to teacher education programs. Retention was found to be higher among “homegrown” teachers or culturally similar teachers. They maintained their positions in schools because of their relationships with and a feeling of responsibility to the community, and the strength of social and cultural connections. Further, knowledge of the local language benefited teachers, students, and families.

Nguyen et al. (2024) provide a systematic analysis of teacher shortages in the United States, highlighting key challenges in quantifying and addressing this critical issue. Their study finds substantial regional and subject-specific variations, with approximately 39,700 vacant teaching positions and 288,000 underqualified teachers nationwide. By emphasizing the need for improved data systems and policy

interventions, this research offers valuable insights into the complex dynamics of teacher shortages and the importance of targeted strategies to mitigate educational inequities.

Gorard et al. (2024) study provides a significant contribution to understanding the international dynamics of teacher shortages by using a Qualitative Comparative Analysis (QCA) approach. The authors analyze teacher supply issues across 18 countries, incorporating a broad range of determinants, such as economic conditions, teacher workload, and societal perceptions of the teaching profession. Their findings emphasize the complex interplay of factors like graduate employment rates, school resources, and teacher stress, offering nuanced insights that inform targeted policy interventions to address global teacher shortage.

As evident across the aforementioned countries, there is a variation in the severity of teacher shortages, specific areas of shortage, and responses to shortages across countries. Thus, an international perspective on teacher shortages needs to be studied to explore global trends. While discussions of both general teacher shortages and specific STEM teacher shortages are often studied, reading and literacy teachers present great importance for student learning. Further consideration of shortages' distribution across schools with high or low SES and variance between schooling systems can provide insights into 20-year trends and opportunities for looking at other countries to inspire policy development in reading teaching.

1.3. Reading teacher specialization

Teacher specialization, which includes teacher education programs with an emphasis on reading pedagogy, has been seen to be positively associated with student reading achievement (Johansson & Myrberg, 2019). Previous research in the United States reveals that teachers holding degrees and certifications in the field they teach in, such as reading or math, are significantly positively correlated with student outcomes (Darling-Hammond, 2000). Teacher education, especially at the primary level, does not universally mandate subject-specific degrees. However, with the knowledge that teachers with specialized training in reading can facilitate better outcomes for their students, there is an opportunity to enhance reading teacher development.

Bos et al. (2001) found that individuals in teacher education programs who perceived themselves as prepared to teach struggling readers were more likely to hold positive views of explicit reading instruction (e.g., phonics/phonetics). They also reported that practicing teachers with such views were more likely to teach phonological awareness. However, Bos et al. (2001) further found that over half of both preservice and in-service educators could not answer nearly half of a set of questions about language structure and phonetics. Taken together, these findings demonstrate a gap between what teachers believe to be helpful for students' learning and what they can effectively teach, given their training and knowledge.

A combination of nationally varying and changing curriculum guidance leads teachers to be best suited to support their students' reading development when they have specialized training in reading. The science of reading examines the psychology of literacy development and language structure as it relates to comprehension (Moats, 2020). Educators can use the science of reading to inform their classroom instruction and assessment practices to better address students' challenges. Furthermore, training in the science of reading can allow teachers to approach new recommendations for reading instruction and curriculum design with informed knowledge of literacy development and student learning.

1.4. The importance of literacy

Establishing a strong basis in reading literacy helps prepare students for success in their later education. Children who show phonological awareness, an aspect of literacy that can be best supported by a well-trained reading teacher, learn to read and spell more easily than students who do not demonstrate phonological awareness (Blachman, 2000). Major phonological development and literacy learning occurs in primary education, setting a foundation for the rest of a student's learning. Students who do not meet reading proficiency standards in the third grade are also more likely to not graduate from secondary school on time (Hernandez, 2011). These outcomes can be amplified when a student experiences poverty at any point in their lives, further decreasing their likelihood of finishing secondary school on time.

Students develop self-perceptions of their reading abilities throughout primary education, developing strongly in the second and third grades (Chapman & Tunmer, 1997). These self-perceptions push students to form assumptions about their own reading abilities, which influences later interest in reading (Stanovich, 2009). Emphasis on supporting students in early reading and literacy can establish foundations for success, building academic confidence that enhances their later experiences.

Special attention to teaching that adequately supports students' literacy development is particularly important in shaping their educational experiences beyond reading and primary schooling.

1.5. Current study

In this study, we analyze five PIRLS cycles (2001–2021) to evaluate shortages of teachers specialized in reading across 65 education systems worldwide (including national and sub-national systems) and to examine disparities by school socioeconomic status and location. We ask.

1. International trend: How have reported shortages of teachers specialized in reading changed over time across these education systems from 2001 to 2021?
2. Socioeconomic inequality: Within these systems, how does the distribution of shortages differ between low- and high-SES schools, and how have these gaps evolved over time?
3. Geographic inequality: Within these systems, how does the distribution of shortages differ between rural and urban schools, and how have these gaps evolved over time?

2. Data and methods

2.1. Data sample

For this study, we utilized data from the International Association for the Evaluation of Educational Achievement's (IEA) Progress in International Reading Literacy Study (PIRLS) across multiple cycles, including data from the 2001, 2006, 2011, 2016, and 2021 cycles. PIRLS is a large-scale assessment that measures the reading literacy of fourth-grade students around the world, providing a rich dataset that includes both student achievement and contextual information about schools, teachers, and home environments.

The data from these five cycles offers a unique opportunity to analyze trends over time, particularly in relation to teacher shortages and how these shortages intersect with school socio-economic status (SES) and location. By leveraging PIRLS data, we can conduct a longitudinal analysis at the country level, examining changes and patterns in educational resources across different countries and contexts.

The sample for each cycle of PIRLS includes a representative selection of schools and students within each participating country, ensuring that the results are both internationally comparable and reflective of the broader educational landscape. In our analysis, we focus specifically on the variables hypothetically related to teacher shortages, school SES, and school location, which are critical factors in understanding the broader context of educational equity and resource distribution.

2.2. Teacher shortage

Our primary variable of interest comes from the PIRLS School Questionnaire. Principals are asked to report how certain shortages or inadequacies affect the school's capacity to provide instruction (Not at all, A little, Some, or A lot). Among other topics, principals are asked to report on the extent to which instruction is affected by a shortage of reading teachers. While the questionnaire has evolved over time, this question has remained mostly consistent across cycles (see Table 1).

In our analysis, we dichotomize principal responses to these items into two groups. In the first group, response options "A little", "Some", and "A lot" were grouped as 0, indicating schools where principals report that a teacher shortage impacts the school's ability to provide instruction. Schools where principals reported that instruction was not affected (i.e., "Not at all") was coded as 1, indicating schools where a teacher shortage did not impact the school's capacity to provide instruction. To see the distribution of responses on the original variable please see Figure A1.

There may be concerns over the loss of information due to the dichotomization of the teacher shortage variable. To confirm the validity of the newly developed teacher shortage measure in this study, we examined the correlation between the mean of the original undichotomized variable and the percentage of the newly constructed teacher shortage variable across all cycles and participating countries. A high correlation would indicate that the construct we created effectively captures the extent of teacher shortages, thereby validating it as a reliable measure for this study. The correlation result of .8875 indicates a strong positive relationship between the mean and percentage of the teacher shortage variable. This high correlation validates our measure, confirming that it effectively represents the teacher shortage construct.

Table 1
Teacher shortage variable across cycles.

Assessment cycle	Target variable	Item	Response category
PIRLS 2001	*ACBGST2*	How much is your school's capacity to provide instruction affected by a shortage or inadequacy of the following?: Teachers qualified to teach reading	1 = Not at all, 2 = A little, 3 = Some, 4 = A lot
PIRLS 2006	*ACBGSI2*	How much is your school's capacity to provide instruction affected by a shortage or inadequacy of the following?: Teachers with a specialization in reading	1 = Not at all, 2 = A little, 3 = Some, 4 = A lot
PIRLS 2011	*ACBG10*BA	How much is your school's capacity to provide instruction affected by a shortage or inadequacy of the following?: Resources for reading instruction: teachers with a specialization in reading.	1 = Not at all, 2 = A little, 3 = Some, 4 = A lot
PIRLS 2016	*ACBG12*BA	How much is your school's capacity to provide instruction affected by a shortage or inadequacy of the following?: Resources for reading instruction: teachers with a specialization in reading.	1 = Not at all, 2 = A little, 3 = Some, 4 = A lot
PIRLS 2021	*ACBG10*BA	How much is your school's capacity to provide instruction affected by a shortage or inadequacy of the following?: Resources for reading instruction: teachers with a specialization in reading.	1 = Not at all, 2 = A little, 3 = Some, 4 = A lot

2.3. Creating socio-economic status (low and high SES) and school location variable (rural and urban)

To examine how teacher shortages vary based on school SES and school location, we created two additional dummy variables: one for school SES and another for school location.

For the school SES variable, we categorized schools as either low or high SES based on principal reports of the percentage of students from economically disadvantaged homes enrolled in the school. The original variable had four categories: 1 = 0–10 %, 2 = 11–25 %, 3 = 26–50 %, and 4 = more than 50 %. We classified schools in category 4 as low SES (coded as 0), and the remaining categories were grouped as high SES (coded as 1). See Table A2 for the number of schools by country and SES category.

School principals report the size of the municipality in which the school is located using seven categories: (a) up to 3000; (b) 3001–15,000; (c) 15,001–30,000; (d) 30,001–50,000; (e) 50,001–100,000; (f) 100,001–500,000; and (g) > 500,000. Given the absence of a single global standard for urban–rural typologies (Rees et al., 2017; United NationsDepartment of Economic and Social AffairsStatistics Division, 2017), we adopted a transparent, instrument-aligned dichotomy: municipalities <100,000 inhabitants are coded **rural (0)** and ≥100,000 inhabitants **urban (1)**—splitting exactly at the PIRLS category boundary between (e) and (f). This choice is also **consistent with widely used NCES locale classifications**, which distinguish metropolitan areas based on Core Based Statistical Area thresholds (≥100,000), alongside micropolitan and noncore areas (NCES, 2023).

2.4. Analytical Strategy

To understand how the prevalence of teachers shortages has changed over time across different countries, we use graphical representations of those trends. In addition to these trend plots, we examine how changes in the prevalence of teacher shortages has varied by SES and the location of schools also using graphical representations.

To more formally examine the relationship between teacher shortage percentages and the year of observation, while controlling for country-specific effects, a fixed-effects regression model was employed. First, we construct a country-by-year dataset from the principal responses to each cycles' school questionnaire. Principal responses are averaged for all respondents in each cycle using school sampling weights so that the percentage is representative of the country's school population during the year. Using the country-level dataset, the model is specified as follows:

$$\textbf{Teacher Shortage Percentage (pct)}_{it} = \beta_0+\beta_1 \text{Year}_{2006it}+\beta_2 \text{Year}_{2011it}+\beta_3 \text{Year}_{2016it}+\beta_4 \text{Year}_{2021it}+\alpha_i+\epsilon_{it}$$

Where.

- Teacher Shortage Percentage $(\text{pct})_{it}$: The percentage of teacher shortage for country i in year t.
- β_0: The intercept, representing the average teacher shortage percentage in the reference year 2001.
- β_1, β_2, β_3, β_4: Coefficients for the dummy variables representing the years 2006, 2011, 2016, and 2021, respectively. These coefficients capture the change in teacher shortage relative to the reference year 2001.
- α_i: Country-specific fixed effects, accounting for unobserved time-invariant heterogeneity across countries.
- ϵ_{it}: The error term, capturing random variation not explained by the model.

This model allows us to isolate the change in teacher shortages across cycles, focusing on changes within-country. That is, the inclusion of

country-fixed effects in the model allows us to estimate how teacher shortages change over time, on average, within-countries, removing any between-country variation in teacher shortages.

We modify the model above to estimate how trends in teacher shortages vary by school SES and location. The model uses a modified dataset from the one described above. Instead of country-by-year observations, the new dataset uses a country-by-year-by-school characteristics (GRP) observation. That is, for each country-year combination, there are two separate observations representing the different levels of school SES and location (i.e., low versus high SES and rural versus urban, respectively). The model is specified as follows:

$$\textbf{\textit{Teacher Shortage Percentage (pct)}}_{ijt} = \beta_0 + \beta_1 \text{Year}_{2006it} + \beta_2 \text{Year}_{2011it} + \beta_3 \text{Year}_{2016it} + \beta_4 \text{Year}_{2021it} + \beta_5 \text{GRP}_j + \beta_6(\text{Year}_{2006it} \times \text{GRP}_j) + \beta_7(\text{Year}_{2011it} \times \text{GRP}_j) + \beta_8(\text{Year}_{2016it} \times \text{GRP}_j) + \beta_9(\text{Year}_{2021it} \times \text{GRP}_j) + \alpha_i + \epsilon_{ijt}$$

Where.

- Teacher Shortage Percentage $(\text{pct})_{ijt}$**:** The percentage of teacher shortage for school type j in country i in year t.
- β_0: The intercept, representing the baseline teacher shortage percentage in the reference year 2001 for the baseline school type (i.e., low SES or rural).
- β_1, β_2, β_3, β_4: Coefficients for the dummy variables representing the years 2006, 2011, 2016, and 2021, respectively, representing the changes from the reference year 2001 for the baseline school type (i.e., low SES or rural).
- β_5: The coefficient for GRP, representing the difference in the teacher shortage percentage in the reference year 2001 for schools where GRP = 1 (i.e., high SES or urban).
- β_6, β_7, β_8, β_9: Differences in the coefficients for the dummy variables representing the years 2006, 2011, 2016, and 2021, respectively, for schools with GRP = 1 (i.e., high SES or urban).
- α_i: Country-specific fixed effects, accounting for unobserved heterogeneity across countries.
- ϵ_{it}: The error term, capturing random variation not explained by the model.

The model is estimated separately for the two different school characteristic measures: school SES and location.

3. Results

3.1. International trends in principals concerns over teacher shortages

3.1.1. International patterns

Fig. 1 shows the country-by-country trends in the teacher shortage variable. The figure shows great variation in principal concerns over teacher shortages across countries. For instance, Hong Kong reported the highest rate of shortages of all studied countries of over 98 % of their schools in all 5 survey years. Others show consistent comparatively low shortages although not responding in all 5 years, such as Latvia which always reported shortages between 34 % and 42 % in the four years the country participated (Fig. 1). Scotland also reported low levels of shortage in 2001 and 2006, the only two years with available data, where it decreased from 14 % of schools to 8.7 %. The lowest reported shortage was in Bulgaria in 2021, at 5.3 % after progressively decreasing throughout the four years the country participated in PIRLS. These large differences between countries demonstrate that the level of reading teacher shortage is not a universally experienced issue, and thus country-level examinations are necessary to understand trends over

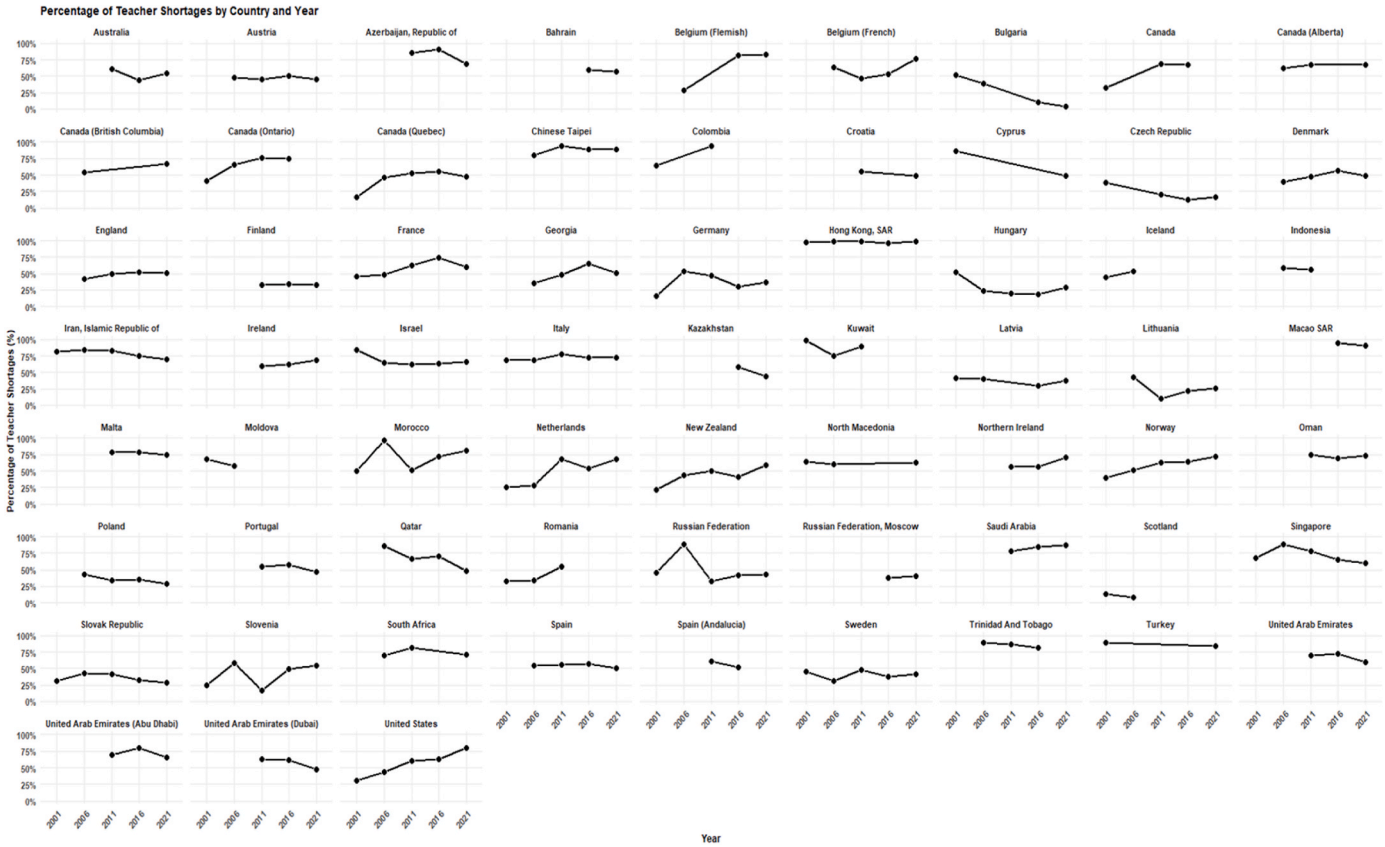

Fig. 1. Percentage of principals concerned with teacher shortages by country and year.

time.

Trends in teacher shortages also appear to differ by country. Some countries have substantial increases in their reading teacher shortages between 2001 and 2021. Notably, in the United States there was a 37.69 percentage point increase in schools reporting shortages over the 20 year period. In 2001 33.74 % of schools surveyed reported a reading teacher shortage, by 2021 the number rose to 71.43 %. The Netherlands observed a similarly large increase from 26.05 % in 2001 to 65.35 % in 2021. While the United States saw a consistent increase over time, the Netherlands reported a decrease from 68.1 % in 2011 to 56.41 % in 2016. Bulgaria's reported shortage fell over 40 percentage points from 45.7 % of schools in 2001 to 5.3 % in 2021 in the four survey years the country participated in PIRLS (see appendix). The reported percentage of schools with reading teacher shortages in Iran decreased from 86.5 % to 66.8 % over the same period. Russia also reported a period of decrease from 84.72 % in 2006 to 36.6 % in 2011, followed by a steady increase in both 2016 and 2021 to 44.33 %. These trends indicate that national-level teacher shortages are not only unstable and differing by country, but that the trends within countries can change across time as well.

3.1.2. Fixed-effects regression analysis

We next attempt to summarize the information provided in Fig. 1 by examining the average within-country trends across the wide set of countries. The fixed-effects regression model examines teacher shortages across all countries in the dataset using up to 260 country-by-year observations, providing insightful findings (Table 2). We look at the regression estimated for different samples of the dataset based on the number of data points each country has. In the baseline year 2001, the average teacher shortage across all countries was estimated at 52 %, a highly statistically significant figure (SE = 3.42, $p < .001$) (Table 2). This robust baseline suggests a widespread issue of principal concerns over teacher shortages at the beginning of the period studied. Changes in concerns over teacher shortages in 2006 compared to 2001 were not found to be statistically significant (SE = 3.02). Significant increases in teacher shortages were observed in 2011 and 2016, with increases of 6.86 percentage points (SE = 3.00, $p < .05$) and 6.72 percentage points (SE = 3.03, $p < .05$), respectively, compared to the 2001 baseline. These results suggest that, on average, concerns over teacher shortages were increasing during these periods. However, the change observed in 2021, estimated to be 5.50 percentage points (SE = 2.99) compared to 2001, was not statistically significant, indicating that this observed rise might be attributable to random variation. Importantly, the model controls for country-specific factors that remain constant over time, ensuring that the observed changes in teacher shortages are not confounded by between country differences in teacher shortages. Overall, the findings indicate a notable and statistically significant increase in teacher shortages from 2001 to 2011 and 2016, while the changes in 2006 and 2021 may reflect random fluctuations rather than a consistent trend.

In order to contextualize the main findings, we decomposed the variance in teacher shortage across all country-by-year observations using an analysis of variance with year (categorical), country, and the interaction between them. This analysis showed that 76 percent of the total variance in teacher shortage in the country-by-year observations related to differences between countries, 2 percent was linked to international differences between year points, and 22 percent pertained to the interaction between countries and year. Given that we found that the main source of the variance was between countries, we would suggest that we should not overinterpret the extent of observed international trends.

Several alternative models using more restricted country samples confirmed the robustness of the main findings. The fixed-effects regression model for countries that participated in at least five years of the study, using 90 country-by-year observations, reveals significant insights into teacher shortages over time. In the baseline year of 2001, the average teacher shortage in these countries was estimated at 46.8 % (SE = 5.13, $p < .001$). By 2006, teacher shortages had increased by 12.1 percentage points compared to 2001, with this increase being statistically significant ($p < .01$). In 2011, the teacher shortage was 9.47 percentage points higher than in 2001 (SE = 4.48, $p < .05$), indicating a reliable, albeit slightly less pronounced, increase. The trend continued in 2016, with a 9.15 percentage point increase (SE = 4.48, $p < .05$), and in 2021, with a substantial increase of 12.6 percentage points (SE = 4.48, $p < .05$). These findings highlight a shift in teacher shortages in countries with longer participation in the study, with statistically significant increases observed after 2001 that appear to have remained relatively stable in subsequent years.

The analysis of countries that responded in all five years showed that 67 percent of the total variance in teacher shortage in the country-by-year observations related to differences between countries, 4 percent was linked to international differences between year points, and 29 percent pertained to the interaction between countries and year. Given that we found that the main source of the variance was between countries, we would suggest that we should not overinterpret the extent of the observed international trend. Some countries reported consistently high levels of teacher shortages, while others reported consistently relatively low shortages, and others demonstrated changing levels of shortages over time.

3.1.3. Summary of findings

The results from the regression analysis indicate that, on average, principals' concerns over teacher shortages increased somewhat since the initial administration of the item in PIRLS, particularly in the 2011 and 2016 cycles. This suggests that there is a slight increasing trend in concerns over teacher shortages over time that has remained steady since the latter part of the decade. Variance decomposition indicates that most of the variation in principals' concerns over the happens between countries indicating that it is more of a concern in some countries compared to others, suggesting that countries may be able to learn from others' experiences in how to successfully mitigate teacher shortage concerns.

Table 2
Fixed effect model results estimating trends in principals concerns over teacher shortages.

	Country Samples				
	All Countries (1)	*>=2 Participation (2)*	*>=3 Participation (3)*	*>=4 Participation (4)*	*>=5 Participation (5)*
Intercept (2001)	52 (3.42) ***	50.3 (3.72) ***	47.8 (4.11) ***	46.1 (4.60) ***	46.8 (5.13) ***
Year2006	5.58 (3.02)	5.58 (3.02)	7.20 (3.27) *	9.47 (3.71) *	12.1 (4.48) **
Year2011	6.86 (3.00) *	6.86 (3.00) *	7.71 (3.19) *	6.53 (3.75)	9.47 (4.48) *
Year2016	6.72 (3.03) *	6.73 (3.03) *	7.89 (3.21) *	6.94 (3.68)	9.15 (4.48) *
Year2021	5.50 (2.99)	5.50 (2.99)	7.35 (3.22) *	7.62 (3.71) *	12.6 (4.48) *
Country-fixed effects	yes	Yes	Yes	Yes	Yes
n (country-by-year observation)	260	234	206	146	90

Fig. 2. Percentage of teacher shortages by country, year, and socioeconomic status in Europe.

3.2. International trends in principals concerns over teacher shortages by school socioeconomic status

3.2.1. International patterns

We next explore how trends in concerns over teacher shortages differ by the SES of students enrolled in the school (Figs. 2–4). There is variation in the distribution of reading teacher shortages between low socioeconomic status and high socioeconomic status schools. While some countries present a more equal distribution of the shortage, others observe that a higher percentage of low socioeconomic status schools report reading teacher shortages than the percentage of high socioeconomic status schools that do.

When looking at the data divided by socioeconomic status the red line is the percent of low socioeconomic status schools reporting shortages, the green line is high socioeconomic status schools, and the blue line is the percentage of schools reporting teacher shortages throughout the country. It is important to note that some countries have fewer schools in either the low or high socioeconomic status categories compared to the number of schools in the other category (see Appendix).

The United States is a case where the teacher shortage has been increasing over the study period and the trends in both low and high socioeconomic status schools have followed a general increasing trend. The percentage of high socioeconomic status schools reporting shortages gets close to the percentage of low socioeconomic schools in 2011, before splitting again. In 2021 the gap between low and high socioeconomic status schools was about 25 %. The results show that while teacher shortages in the United States are increasing, the increase has been occurring more prominently in low socioeconomic status schools since from 2001 to 2006 and 2011 to 2021.

Other countries show less extreme unequal distribution but still consistently more shortages in low socioeconomic status schools. New Zealand follows a similar pattern as the United States, but with lower overall teacher shortages, where the gap between low and high socioeconomic status schools converged in 2011 before increasing again in both 2016 and 2021, so a lower percentage of high socioeconomic status schools report shortages. In Hungary, the gap between low and high socioeconomic status schools was largest in 2001, and the data for both follows the pattern of overall teacher shortages, while the gap shrank over time.

Some countries have closer to equal distribution of their country's reading teacher shortage in low and high socioeconomic status schools. For example, Hong Kong noted minimal differences across years, with the percentage of principals reporting reading teacher shortages remaining consistently high—97.3 % in 2001, 99.5 % in 2006, 99.2 % in 2011, 95.9 % in 2016, and 98.4 % in 2021. Similarly, Morocco's data for both groups was nearly equal until it started to diverge in 2016, and in

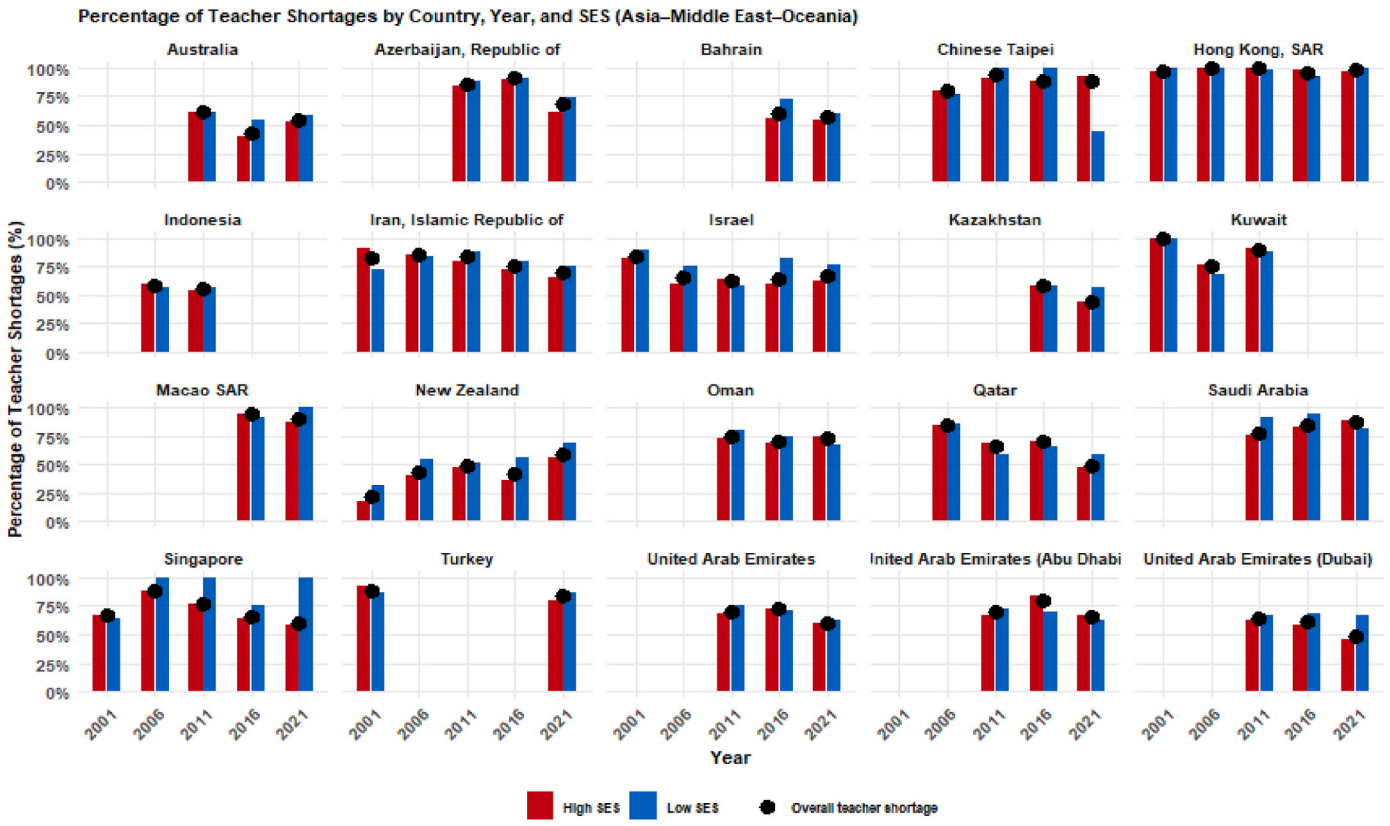

Fig. 3. Percentage of teacher shortages by country, year, and socioeconomic status in Asia–Middle East–Oceania.

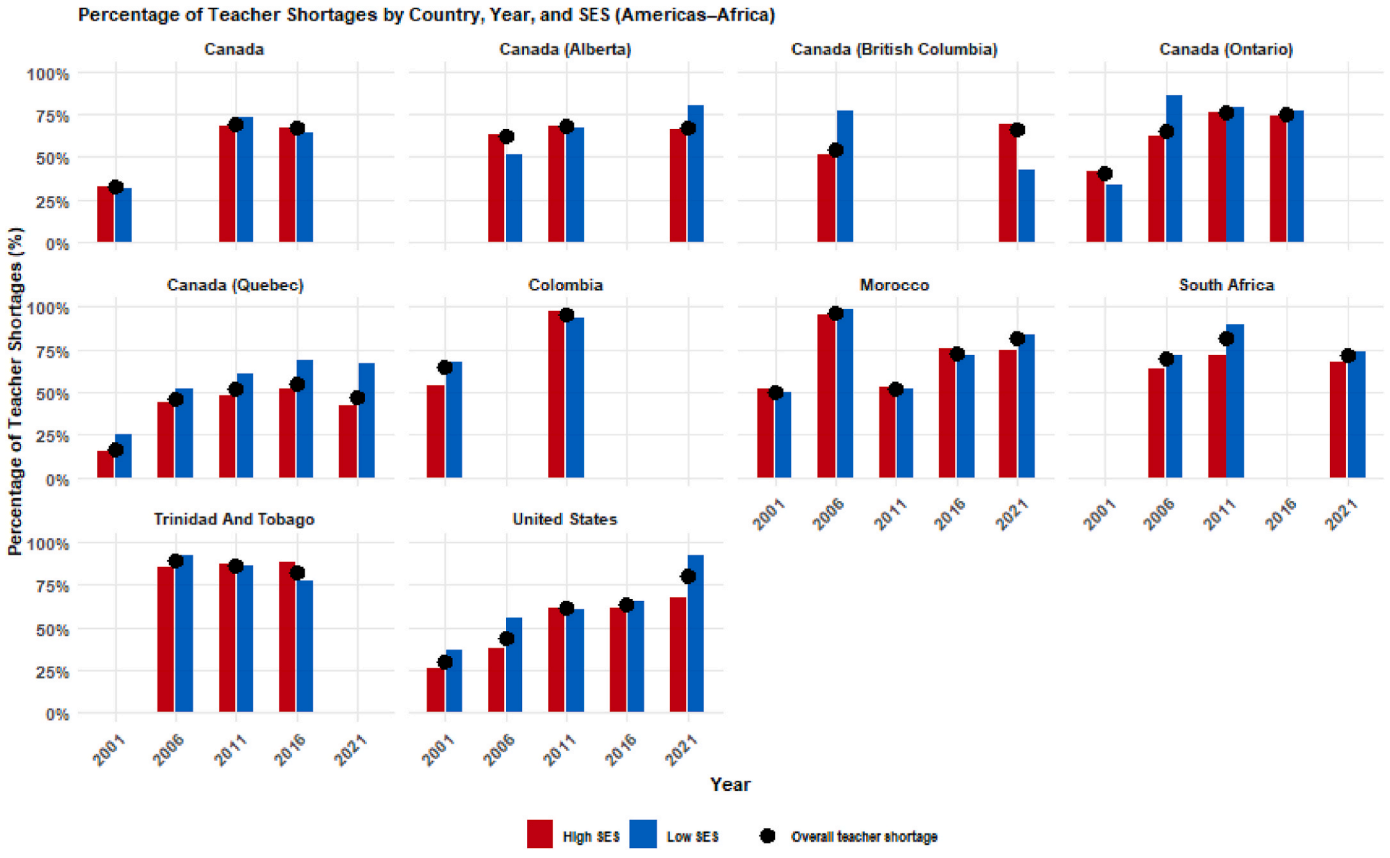

Fig. 4. Percentage of teacher shortages by country, year, and socioeconomic status in Americas–Africa.

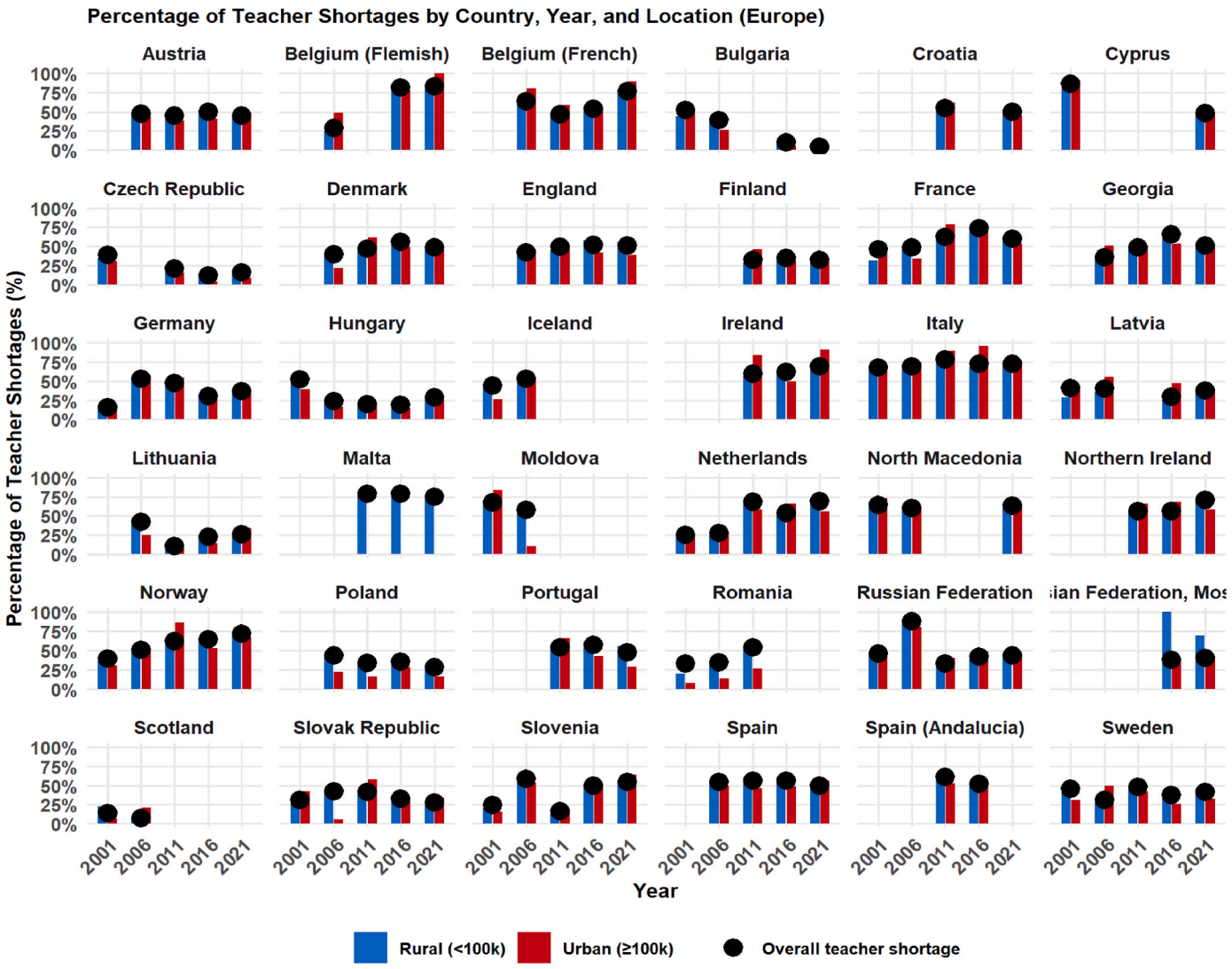

Fig. 5. Percentage of teacher shortages by country, year, and school location in Europe.

2021 there was a gap of about 5 % with low socioeconomic status schools reporting more shortages.

The distribution between low and high socioeconomic status schools is not fixed, as seen in countries that either became more equalized or more unbalanced over time. Sweden began with 33 percent of low socioeconomic status schools reporting reading teacher shortages, compared in 50 percent of high socioeconomic status schools. The difference flipped in 2006 and 2011, where there was more of a shortage in low socioeconomic status schools. In 2016 and 2021, the gap more similarly resembled 2001, where there was a greater proportion of high socioeconomic status schools with shortages.

3.2.2. *Fixed-effects regression analysis*

To look at the average trends across countries, we conduct a fixed-effects regression analysis investigating the relationship between teacher shortage, cycle, socioeconomic status of the school, and their interactions across a sample of countries from 2001 to 2021. The regression examines the relationship between the concerns over teacher shortages, cycle, and school SES. The analysis was conducted using all available countries, consisting of 520 (260 x 2) country-by-year-school-SES observations (for description of the dataset see Analytical Strategy section). The model controls for country-specific time invariant effects (see Table 3).

The baseline level of teacher shortage in 2001 for the lower SES school group was estimated at 53.1 % (SE = 3.65, $p < .001$). Significant increases in teacher shortage were observed over time, with increases of 7.20 percentage points in 2006 compared to 2001 (SE = 3.25, $p < .05$), 9.83 percentage points in 2011 compared to 2001 (SE = 3.18, $p < .01$), and 7.54 percentage points in 2016 compared to 2001 (SE = 3.20, $p < .05$) relative to 2001. The difference between 2001 and 2021 did not reach statistical significance ($p = .071$), although the direction of the coefficient would suggest an increase compared to the baseline 2001

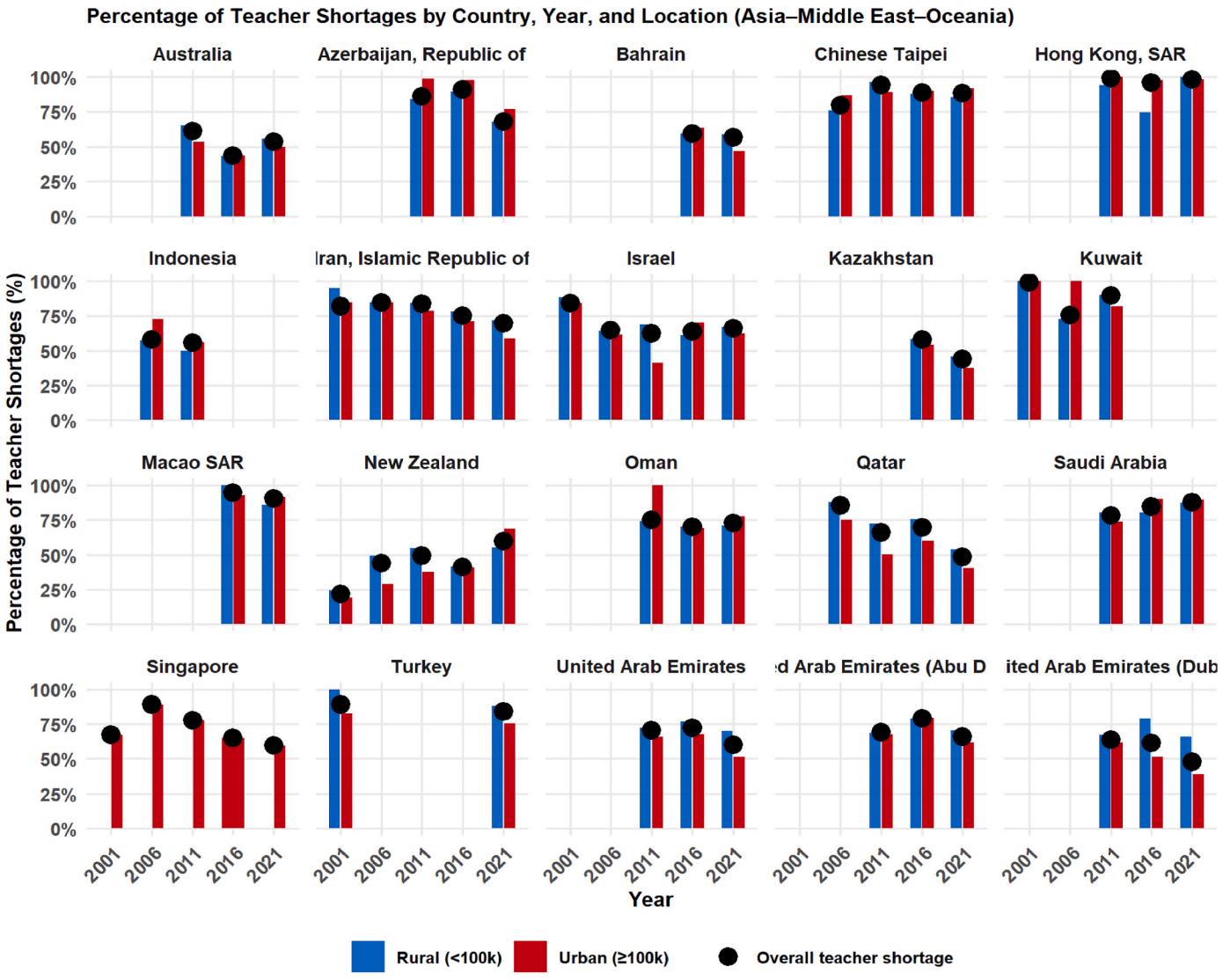

Fig. 6. Percentage of teacher shortages by country, year, and school location in Asia–Middle East–Oceania.

year.

The coefficient on the high-SES school indicator suggests that the concern over teacher shortages in the school was 2.39 percentage points lower than in low-SES schools group in the baseline cycle of 2001, however, this difference was not statistically significant ($p = .466$). Interaction terms between year and the school SES indicator, suggest that the difference in concerns over teacher shortages between high- and low-SES schools were similar over time when compared against the baseline year.

3.2.3. *Variance decomposition analysis*

To further understand the factors contributing to variations in teacher shortage, a variance decomposition analysis was conducted (see Table 4). The results revealed that between-country differences accounted for the largest proportion of variance in teacher shortage, explaining 65.40 % of the total variance. This indicates that most of the variation in teacher shortage is due to differences between countries. Year effects contributed a relatively small portion of the variance (1.79 %), suggesting that while teacher shortages have increased over time, this trend accounts for only a small fraction of the total variance. Socioeconomic status (SES) differences accounted for a minor portion of the variance (.48 %), implying that differences in teacher shortages between socioeconomic groups are relatively modest.

Interaction effects provided additional insights: the interaction between year and country accounted for 21.67 % of the variance, highlighting that the impact of year on teacher shortage varies significantly across countries. The interaction between year and SES explained a negligible amount of variance (.09 %), reinforcing the earlier finding that the influence of SES on teacher shortage does not significantly change over time. The interaction between country and SES explained 5.25 % of the variance, suggesting some variation in how SES influences teacher shortages across different countries.

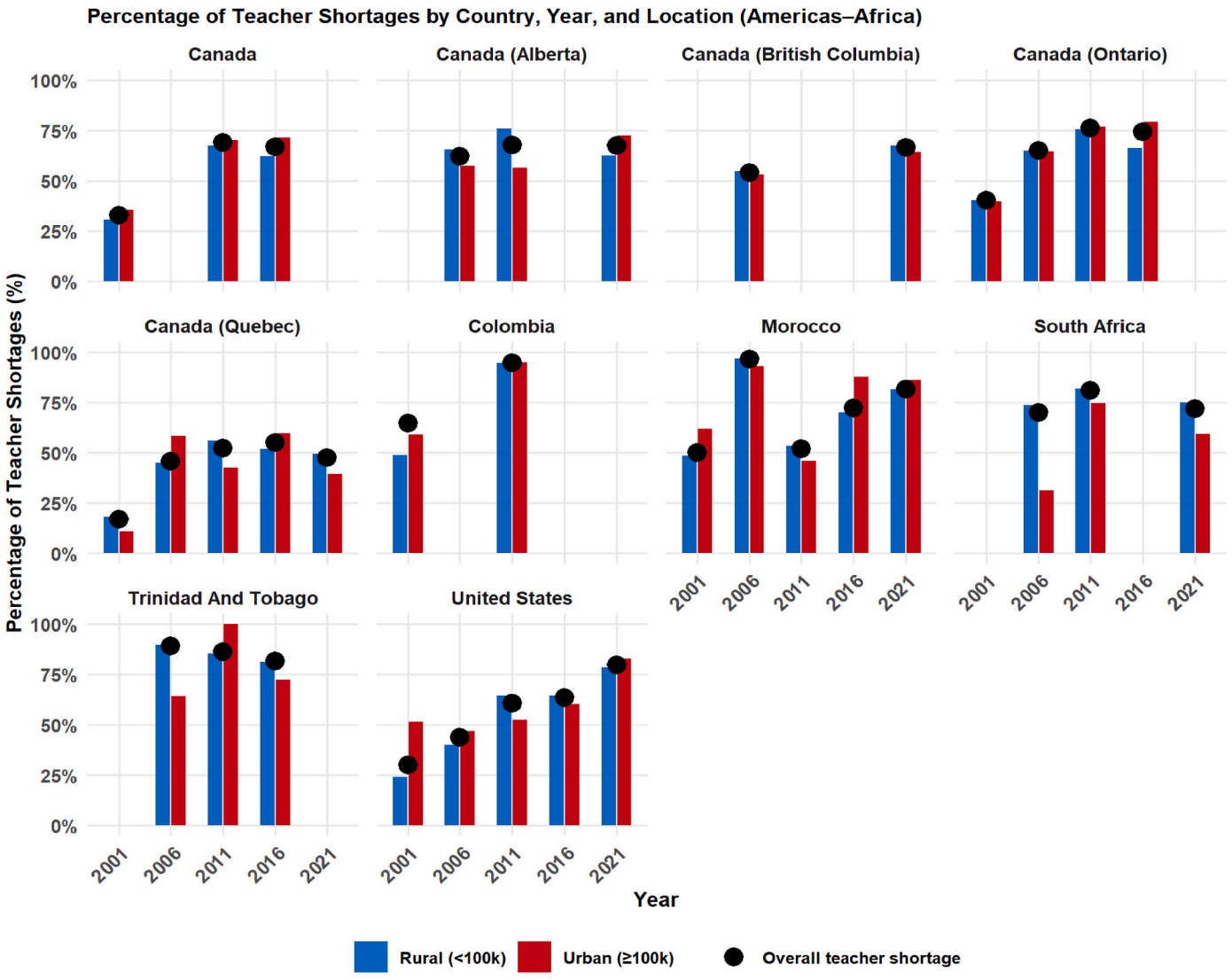

Fig. 7. Percentage of teacher shortages by country, year, and school location in Americas–Africa.

Table 3
Fixed effect model results estimating trends in principals' concern over teacher shortage by year and socioeconomic status (SES).

Variable	Estimate	Std. Error	t-value	Pr(>|t|)	Significance
Intercept (2001)	53.1	3.65	14.6	<.001	***
Year2006	7.20	3.25	2.21	.028	*
Year2011	9.83	3.18	3.09	.002	**
Year2016	7.54	3.20	2.36	.019	*
Year2021	5.67	3.14	1.81	.071	
High-SES	−2.39	3.27	−.73	.466	
Year2006 x High-SES	−.506	4.37	−.12	.908	
Year2011 x High-SES	−3.10	4.20	−.74	.460	
Year2016 x High-SES	−.164	4.18	−.04	.969	
Year2021 x High-SES	.574	4.08	.14	.888	

3.2.4. *Summary of findings*

Our analyses indicate that while teacher shortages have generally increased over the past two decades, the majority of variance in these shortages is due to differences between countries rather than changes over time or differences in socioeconomic status. The fixed-effects regression analysis revealed significant increases in principals' concern over teacher shortages in 2006, 2011, and 2016 compared to 2001 with the effect being relatively uniform across socioeconomic groups. Variance decomposition further highlighted the predominant role of between-country differences in explaining teacher shortages, with relatively minor contributions from year-to-year changes and socioeconomic status.

These findings suggest that addressing teacher shortages may require targeted interventions at the country level, as the variation between countries is the most significant factor. Additionally, socioeconomic status does not appear to have a significant effect across time, indicating that systemic issues at the country-level may be more critical in driving teacher shortages. However, these results only speak to the average

Table 4
Variance decomposition analysis of principals' concern over teacher shortage by year and socioeconomic status (SES).

Component	Variance (%)
Between Countries	65.40
Between Years	1.79
SES	.48
Interaction Year-Country	21.67
Interaction Year-SES	.09
Interaction Country-SES	5.25

across countries. The analysis of trends presented in Figs. 2–4, do indicate some differences across countries. Thus, the consideration of socioeconomic status should differ between countries based on different levels of unequal distribution of shortages.

3.3. International trends in principals concerns over teacher shortages by school location

3.3.1. International patterns

We next explore how trends in concerns over teacher shortages differ by the location of schools (i.e., urban versus rural) (Figs. 5–7). Individual country trends in the distribution of teacher shortages between rural and urban schools differ and change over the 20-year period, similar to what is observed in the socioeconomic status variable.

In the United States, the gap between rural and urban schools became smaller in both 2016 and 2021, though the percentage of shortages in each increased in both years. In 2001, urban schools had more reading teacher shortages than rural schools, however in 2011 this changed and there was a higher proportion of rural schools that reported shortages.

We also observe changes in Sweden, where in all years, except 2006, rural schools reported a greater percentage of shortages than urban schools. In New Zealand, urban schools consistently had less shortages until 2016, when they were about even with rural schools and in 2021 a greater percentage of urban schools reported shortages than rural schools did.

3.3.2. Fixed-effects regression analysis

To look at the average trends across countries, we conduct a fixed-effects regression analysis investigating the relationship between teacher shortage, cycle, school location, and their interactions across a sample of countries from 2001 to 2021. The fixed-effects regression analysis examines the relationship between teacher shortage, year, and school location (Table 5). The analysis was conducted using all available countries, comprising 514 (257 × 2) country-by-year–school location observations (see Analytical Strategy section for dataset details). The total number is smaller than in the SES analysis because, in some countries, one of the school location groups (urban or rural) was not represented in the data, leading to exclusion due to missing subgroup information. The baseline level of principals' concerns over teacher shortages in 2001 for rural schools (the baseline school location category) was 47.9 % (SE = 3.88). This result is highly significant ($p < .001$). Year effects indicate that there was not a significant rise between 2001 and 2006. Significant increases were observed in 2011 (9.70 percentage points, $p = .007$), 2016 (9.94 percentage points, $p = .006$), and 2021 (7.91 percentage points, $p = .026$). These results indicate that teacher shortages have significantly worsened in those cycles compared to the baseline observation in 2001.

The coefficient on the urban school indicator suggests that the concern over teacher shortages urban schools was .898 percentage points higher than in rural schools in the baseline cycle of 2001, however, this difference was not statistically significant (p = .809). Interaction terms between year and the school location indicator, suggest that the difference in concerns over teacher shortages between urban and rural schools were similar over time when compared against the baseline year.

3.3.3. Variance decomposition analysis

To further explore the factors contributing to the variation in principals' concerns over teacher shortages, a variance decomposition analysis was conducted. This analysis helps to understand how much of the variation in concerns over teacher shortages can be attributed to differences between countries, years, and school location (Table 6). The majority of the variance in teacher shortage (60.97 %) is due to differences between countries. This suggests that country-specific factors (such as education policies, economic conditions, and teacher recruitment practices) play a significant role in determining teacher shortages. A small portion of the variance (2.32 %) is attributed to differences across years, indicating that while teacher shortages have increased over time, these changes account for a relatively small part of the overall variance. The variance due to location differences is minimal (.15 %), suggesting that location (urban vs. rural) has little impact on the overall teacher shortage across countries.

The interaction between year and country accounts for a significant portion of the variance (19.41 %). This suggests that the impact of year on teacher shortage varies considerably across different countries. The interaction between year and location contributes very little to the variance (.11 %), reinforcing the finding that the relationship between teacher shortage and location is stable over time. The interaction between country and location accounts for 12.42 % of the variance, indicating that the effect of location on teacher shortage varies somewhat across different countries.

Table 5
Fixed effect model results estimating trends in principals' concern over teacher shortage by year and school location.

Variable	Estimate	Std. Error	t-value	Pr(>|t|)	Significance
Intercept (2001)	47.9	3.88	12.3	<.001	***
Year2006	5.75	3.68	1.56	.119	
Year2011	9.70	3.60	2.70	.007	**
Year2016	9.94	3.64	2.73	.006	**
Year2021	7.91	3.54	2.23	.026	*
Urban	.898	3.71	.242	.809	
Year2006 x Urban	−1.65	4.94	−.334	.738	
Year2011 x Urban	−2.61	4.72	−.552	.581	
Year2016 x Urban	−4.34	4.73	−.919	.358	
Year2021 x Urban	−3.48	4.60	−.757	.449	

Table 6
Variance decomposition analysis of principals' concern over teacher shortage by year and school location.

Component	Variance (%)
Between Countries	60.97
Between Years	2.32
LOC	.15
Interaction Year-Country	19.41
Interaction Year-LOC	.11
Interaction Country-LOC	12.42

3.3.4. Summary of findings

The results indicate that concerns over teacher shortages have increased over time, with notable changes in 2011, 2016, and 2021 when compared to 2001. However, the impact of school location on teacher shortages is not significant, and the differences in teacher shortages between locations have remained relatively stable over time (see Table 5). The variance decomposition analysis highlights that the majority of the variance in teacher shortages is due to differences between countries, with relatively small contributions from year-to-year changes and location differences. This again suggests that country-specific factors are the primary drivers of teacher shortages, and interventions to address these shortages should be tailored to the specific needs and circumstances of each country.

4. Discussion

This study examines teacher shortages through a lens that goes beyond only having a sufficient quantity of teachers, but having enough qualified teachers to meet the needs of schools and students. Tracking data over time provides insights into changing teacher workforces across countries, as well as both stagnant and changing equity concerns in socioeconomic status and geographic location. Evaluating teacher shortages not only between countries, but within countries is critical in light of the United Nations' Sustainable Development Goal 4 to achieve access to high quality education for all students, regardless of wealth status, by 2030.

While the study finds minimal changes in the international levels of reading teacher shortages from 2001 to 2021, examinations of individual countries show that many are experiencing increasing teacher shortages. This increase is also not a universal trend, as some countries experienced decreases in shortages or remained stable. Bulgaria's reported decrease of over 40 percentage points aligns with the country joining the European Union. After joining in 2007, the Bulgarian government implemented a national teacher education program with new standards of teacher training to comply with EU mandates (Aykac & Sahin, 2018). This is an example of an instance of the sociopolitical contexts of a country influencing its education system. Further, the large decrease in Bulgaria's shortage demonstrates that changes in policies could provide opportunities to decrease national teacher shortages. While countries such as the United States, New Zealand, and Norway are experiencing increasing trends, looking to countries with decreases could be a starting point for considering opportunities to address the chronic shortages they experience.

4.1. Socioeconomic equity

In light of Sustainable Development Goal 4's emphasis on eliminating wealth disparities in education, the likelihood of experiencing a teacher shortage in a school that is classified as low versus high socioeconomic status is relevant. Despite not finding significant differences in principals' concerns over teacher shortages based on school SES, on average, differences were still observed across countries. These differences across low and high SES schools within countries suggests that education policies, and the broader social, cultural, and economic systems in a country, can play a role in influencing how students experience shortages. Further, national trends across the 20-year period demonstrate that both rates and distributions of shortages are not fixed within individual countries, providing opportunities to look to countries with lower levels or different distributions of shortages to understand possible methods to address the issue.

For example, the distribution of teacher shortages in Sweden is proportionally higher in more socioeconomically advantaged schools in 2001, 2016, and 2021. Sweden's approach to education has been social democratic, with the slogan "school for all" driving efforts since the 1960s (Göransson et al., 2012, 2013). In the 1990s legislation promoting school choice and private independent schools pushed a shift towards a market-based approach (Lundström & Parding, 2011). Within the marketized system, students and families still do not have to pay for education, even in private schools, as the government pays for it in alignment with the "school for all" approach. Sweden's approach to education focuses on increasing education among students while emphasizing social equity. The Swedish government also incentivizes teachers to work in schools with "difficult conditions" where students have low socioeconomic status backgrounds by offering higher pay through government grant programs (*Statsbidrag f*ör karriärtjänster, 2024). Their values in education and incentive approach are reflected in the distribution of their teacher shortages in 2001, 2016, and 2021, where there was a lower percentage of low socioeconomic status schools reporting reading teacher shortages than high socioeconomic status schools. However, the years 2006 and 2011 report more shortages for low socioeconomic status schools, supporting the notion that even national trends teacher shortages are not fixed and require attention beyond single-year evaluations.

Hungary and the Slovak Republic are countries that demonstrate possibilities to change an unequal distribution of shortages that impacts low socioeconomic schools at a higher rate to one that is more evenly distributed across school demographics over the 20-year period. While each started with a greater proportion of low socioeconomic status schools reporting shortages, by 2021 both counties had a smaller gap, and the Slovak Republic reported proportionally fewer shortages in low socioeconomic status schools than high. These results emphasize the opportunity to address uneven distributions of teacher shortages, specifically as it impacts low SES students. From the perspective of Bourdieu's theory of social reproduction, the results from both countries are notable because they present areas for further exploration into politics and practices in these countries that could alleviate unequal resource distribution.

In the United States, the distribution of shortages shows that low socioeconomic status schools are more likely to experience shortages than high socioeconomic status schools. This trend exemplifies Bourdieu's social reproduction, as students who are already at a disadvantage receive fewer resources, in the form of quality teachers. Preceding the available 2001 PIRLS data, the gap in test scores between students from low- and high-income families in the United States increased from about .6 points for students born in 1943 to 1.25 points for students born in 2001 (Reardon, 2018, pp. 536–550). Thus, low socioeconomic status students are already predisposed to having lower academic success, and the higher prevalence of teacher shortages in their schools reproduces this inequality by providing students who are already more likely to be successful with more qualified teachers. Bourdieu's theory highlights that this then reproduces existing class positions for students by denying them access to resources that can support their educational achievement. Ultimately, in the United States and countries with similar distributions of a higher percent of low SES schools with teacher shortages, students who are already more prone to struggling in school are also more likely to have fewer and less qualified teachers, further driving gaps between low and high SES students and communities.

4.2. Geographic distribution

As with socioeconomic status, the relationship between urban and rural schools and teacher shortages varies between countries, although averaged within-country patterns do not show differences. While countries like Germany and Hungary show relatively consistent trends in the relationships between percentage of teacher shortages in rural versus urban schools, others see changes between 2001 and 2021. The results demonstrate not only internationally varying levels of difficulty staffing schools based on location, but variance within countries as well.

For instance, rural schools in the United States oftentimes struggle to meet their staffing needs. Specifically, schools that are both low socioeconomic status and rural experience high rates of teacher turnover (Ingersoll & Tran, 2023). The results in both 2011 and 2016 reflect this

phenomenon, where rural schools are more likely to report teacher shortages than urban schools. However, in 2001, 2006, and 2021 urban schools were more likely to report teacher shortages, highlighting critical nuance in the discussion of location-based teacher shortages. Urban schools in the United States also face supply issues with often larger student populations and remedy their need for teachers by hiring uncertified and inexperienced teachers (Jacob, 2007). Previous findings in both rural and urban schools confirm the complexity of geographically based teacher shortages. These variances in the relationship between geographic location and teacher shortages emphasize the value of long-term studies of teacher shortages rather than looking at single-year points to assess them.

4.3. Implications for future policy

All countries reported some degree of a principals' concerns over reading teacher shortages throughout the surveyed period. Particularly for countries with shortages that are getting worse with time, there are opportunities to increase the number and quality of teachers in schools.

Countries with uneven distributions of shortage between low and high SES schools can look to other models for education systems to consider reforms to address social reproduction and improve socioeconomic mobility through education. While policies may work in one country, it is important to note that different sociocultural, economic, and political contexts must be accounted for when considering policy-based approaches from other countries.

For example, China has attempted to approach the issue of insufficient teacher supply in rural schools by having high quality urban teachers rotate to rural schools through the Teacher Rotation Policy and compensating them with opportunities for promotion (Liao et al., 2019). Some countries have more decentralized education systems that have separate urban and rural districts, such as the United States. In the United States, a culture of collective bargaining power for teachers works against a policy such as China's Teacher Rotation Policy as transfer rights favor more senior and experienced teachers (Anzia & Moe, 2014). Thus, the United States likely could not implement such a policy presently and have an outcome where highly qualified teachers could be mandated to rotate into rural schools. However, the United States does offer up to $17,500 in student loan forgiveness for teachers who spend at least 5 years teaching in low-income schools (Teacher loan forgiveness, n.d.). This approach, which is less impacted by districts and teacher bargaining further demonstrates how policy considerations in the face of many national teacher shortages must be considerate of prevailing contexts.

Ultimately, individual education systems will have differing solutions to teacher shortages based on the rate it is increasing, if at all, in their countries, potential causes for this increase, and existing political and educational structures. While those that have either lower levels of shortage or more equitable distribution of them can provide inspiration for solutions, countries concerned about social reproduction and meeting the Sustainable Development Goal 4 must be aware of the current state of their countries in order to make informed political decisions. Policies that do not consider existing inequity can continue to perpetuate existing social structures, and thus those developed in pursuit of achieving equitable access to education and Goal 4 should have informed knowledge about the state of and trends in national teacher shortage distributions.

4.4. Limitations

One limitation to the study is the variation in responses to the survey question by country. Countries may perceive what constitutes a "shortage" differently, which impacts their responses to the PIRLS survey. Definitions of what a "teacher qualified to teach reading" or a "teacher with a specialization in reading" may vary by country (Nguyen et al., 2024). While within-country comparisons are generally more robust than cross-country comparisons, caution is still warranted. The item wording changed between the 2001 cycle and subsequent cycles—for example, shifting from 'qualified to teach reading' to 'specialized in reading'—which may have affected how respondents interpreted the question. Given that definitions of teacher qualification or specialization can evolve over time and differ across countries, even within-country trends may reflect both real changes and changes in how teacher shortages are perceived or reported.

An additional limitation is how the study defines urban and rural, which for the simplicity of representation classifies any area with more than 100,000 residents as urban and less than 100,000 residents as rural. Thus, in a country like Singapore where 100 % of the population is considered to live in an urban area (Urban population, 2024). With a population so prominently urban, it is also more likely for only urban schools to give responses and thus the study may not completely capture the state of rural teacher shortages. Further, a classification into two categories does not account for differences between different sizes of urban areas or an area that's classified as rural but has a population close to 100,000 versus one with a population closer to say 10,000. The findings still provide insight into existing gaps, but further exploration on a country-by-country basis would be necessary when considering policy approaches and reforms.

Another factor that could impact teacher shortages in a given country is changes in the population over time, both in size and in distribution between low and high socioeconomic status. The aim of this study is not to directly compare countries, but rather to evaluate trends in shortages over 20 years, which are impacted by changing populations. Further, the data does not explain trends, but describes them, though population changes and their relationship with teacher shortages is an area for further research.

Additionally, some countries did not participate in all five PIRLS cycles. Countries joined late, stopped participating, or missed one or two years in the middle. While there are 66 countries in the data responding to at least two cycles, there is only data available for all five years in 18 of those countries. We show in the main specification that the findings are mostly robust to the sample of countries used based on data availability.

5. Conclusion

This study sought to explore the international and country trends in reading teacher shortages between 2001 and 2021, including overall shortage rates and the distribution between low and high SES schools and urban and rural schools. The findings demonstrate that while there is no clear trend in overall shortages or the distribution between the economic demographics or location of schools internationally, there is variance between countries and notable findings within individual country trends. Specifically, as the United Nations aims to have equal access to quality education globally by 2030, these findings indicate specific places for improvement in teacher quality and supply as well as countries where equity concerns may be more prominent (UNESCO, 2024). Future research into teacher shortages, on both national and international scales, could expand upon critical points in the data where trends shifted or the gap between the percentage low and high socioeconomic status schools reporting shortages changed to evaluate potential policy or education system-related explanations for these changes. Ultimately, the data highlights the need for country-specific targeted interventions in the face of such notable teacher shortages, and emphasis on equity in countries where already disadvantaged students are receiving fewer resources, in the form of qualified teachers.

CRediT authorship contribution statement

Gratia O'Rafferty: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Nurullah Eryilmaz:** Writing – review & editing, Writing – original draft,

Visualization, Validation, Supervision, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Alec Kennedy:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Data curation, Conceptualization. **Rolf Strietholt:** Writing – review & editing, Writing – original draft, Supervision, Investigation, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix

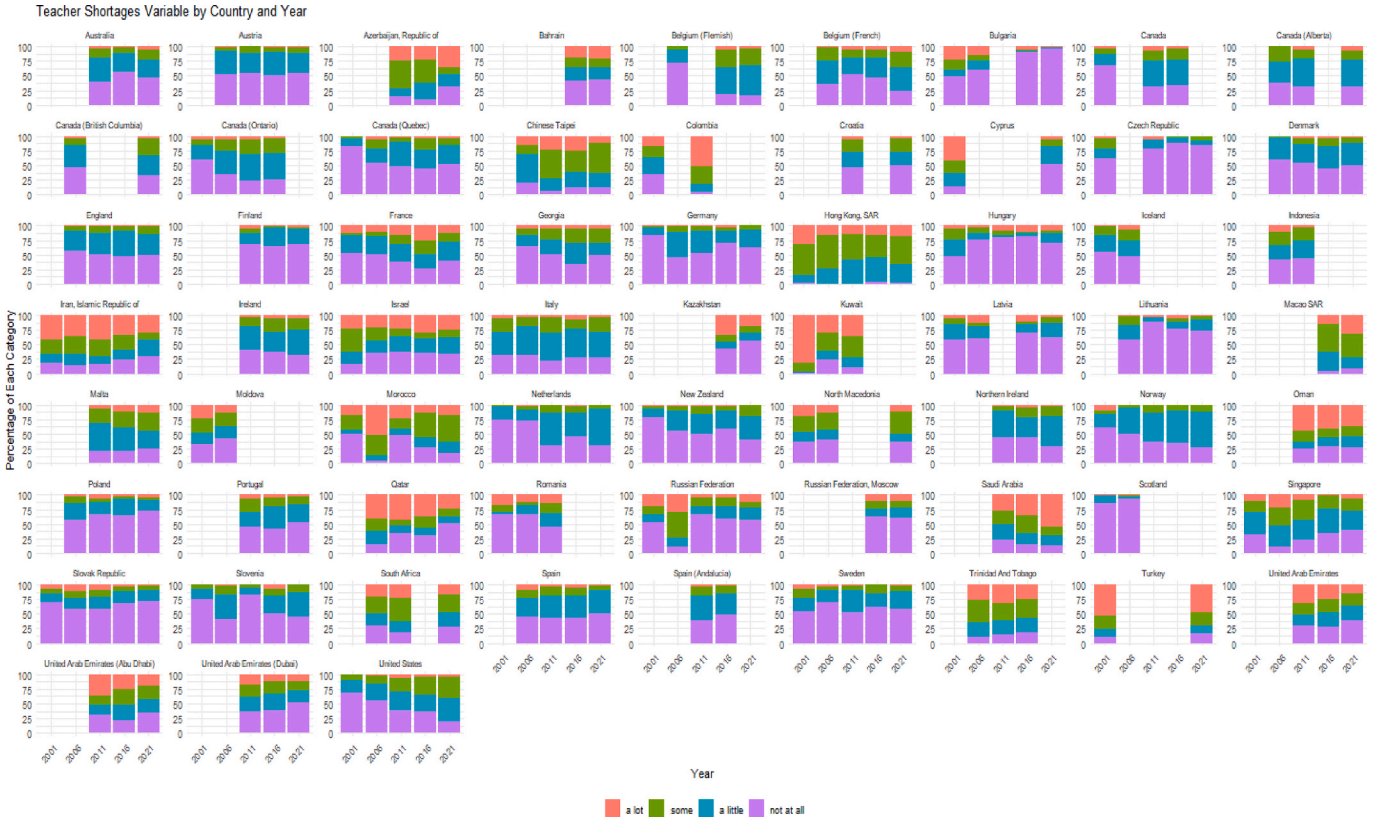

Fig. A1. Distribution of Teacher Shortage Variable by Country and Year.

Table A1
Schools numbers based on Teacher Shortage

Country_name	Years_Info	*YEAR*														
		2001			2006			2011			2016			2021		
		T.S (N-T.S)	N (Mis)	P_TS	T.S (N-T.S)	N (Mis)	P_TS	T.S (N-T.S)	N (Mis)	P_TS	T.S (N-T.S)	N (Mis)	P_TS	T.S (N-T.S)	N (Mis)	P_TS
Argentina	1	58 (64)	138 (16)	47.54												
Belize	1	96 (8)	120 (16)	92.31												
Bulgaria	4	74 (88)	170 (8)	45.68	46 (89)	143 (8)	34.07				10 (143)	153 (0)	6.54	8 (142)	151 (1)	5.33
Canda	3	105 (238)	372 (29)	30.61				663 (409)	1111 (39)	61.85	560 (328)	926 (38)	63.06			
Colombia	2	85 (56)	147 (6)	60.28				135 (10)	150 (5)	93.10						
Cyprus	2	103 (16)	150 (31)	86.55										77 (83)	160 (0)	48.13
Czech Republic	4	48 (88)	141 (5)	35.29				35 (139)	177 (3)	20.11	19 (138)	157 (0)	12.10	35 (157)	196 (4)	18.23
France	5	58 (70)	145 (17)	45.31	70 (83)	169 (16)	45.75	103 (61)	174 (10)	62.80	114 (40)	163 (9)	74.03	106 (64)	184 (14)	62.35
Germany	5	40 (154)	211 (17)	20.62	196 (179)	405 (30)	52.27	97 (86)	197 (14)	53.01	57 (133)	208 (18)	30.00	75 (129)	252 (48)	36.76
Greece	1	94 (41)	145 (10)	69.63												
Hong Kong, SAR	5	136 (2)	147 (9)	98.55	137 (1)	144 (6)	99.28	120 (1)	132 (11)	99.17	131 (3)	138 (4)	97.76	140 (3)	144 (1)	97.90
Hungary	5	98 (105)	216 (13)	48.28	37 (106)	149 (6)	25.87	26 (116)	149 (7)	18.31	22 (122)	149 (5)	15.28	42 (103)	157 (12)	28.97
Iceland	2	50 (64)	133 (19)	43.86	61 (54)	128 (13)	53.04									
Iran, Islamic Republic of	5	154 (24)	184 (6)	86.52	192 (42)	236 (2)	82.05	192 (44)	244 (8)	81.36	213 (57)	271 (1)	78.89	145 (72)	218 (1)	66.82
Israel	5	105 (21)	147 (21)	83.33	86 (44)	149 (19)	66.15	83 (48)	152 (21)	63.36	100 (57)	159 (2)	63.69	109 (57)	194 (28)	65.66
Italy	5	130 (47)	184 (7)	73.45	105 (43)	150 (2)	70.95	151 (43)	202 (8)	77.84	102 (36)	149 (11)	73.91	124 (39)	164 (1)	76.07

(*continued on next page*)

Table A1 (*continued*)

Country_name	Years_Info	*YEAR*														
		2001			2006			2011			2016			2021		
		T.S (N-T.S)	N (Mis)	P_TS	T.S (N-T.S)	N (Mis)	P_TS	T.S (N-T.S)	N (Mis)	P_TS	T.S (N-T.S)	N (Mis)	P_TS	T.S (N-T.S)	N (Mis)	P_TS
Kuwait	3	118 (1)	135 (16)	99.16	103 (29)	149 (17)	78.03	95 (11)	133 (27)	89.62						
Latvia	4	53 (77)	140 (10)	40.77	55 (85)	147 (7)	39.29				51 (99)	150 (0)	34.00	59 (92)	156 (5)	39.07
Moldova	2	104 (40)	150 (6)	72.22	70 (68)	150 (12)	50.72									
Morocco	5	50 (52)	117 (15)	49.02	109 (6)	159 (44)	94.78	141 (119)	284 (24)	54.23	246 (100)	360 (14)	71.10	201 (51)	266 (14)	79.76
Netherlands	5	31 (88)	135 (16)	26.05	37 (81)	139 (21)	31.36	79 (37)	138 (22)	68.10	66 (51)	132 (15)	56.41	66 (35)	131 (30)	65.35
New Zealand	5	34 (114)	156 (8)	22.97	96 (126)	243 (21)	43.24	90 (83)	192 (19)	52.02	83 (87)	188 (18)	48.82	82 (61)	184 (41)	57.34
Norway	5	52 (79)	136 (5)	39.69	68 (56)	135 (11)	54.84	77 (38)	120 (5)	66.96	88 (59)	150 (3)	59.86	111 (44)	158 (3)	71.61
Romania	3	31 (106)	144 (7)	22.63	33 (108)	146 (5)	23.40	68 (79)	148 (1)	46.26						
Russian Federation	5	97 (99)	206 (10)	49.49	194 (35)	232 (3)	84.72	71 (123)	202 (8)	36.60	87 (115)	206 (4)	43.07	90 (113)	204 (1)	44.33
Singapore	5	125 (61)	196 (10)	67.20	156 (19)	178 (3)	89.14	135 (39)	176 (2)	77.59	112 (60)	177 (5)	65.12	108 (73)	183 (2)	59.67
Slovak Republic	5	38 (109)	150 (3)	25.85	53 (109)	167 (5)	32.72	84 (107)	197 (6)	43.98	81 (139)	220 (0)	36.82	55 (110)	169 (4)	33.33
Slovenia	5	31 (95)	148 (22)	24.60	77 (64)	145 (4)	54.61	32 (156)	195 (7)	17.02	77 (75)	160 (8)	50.66	74 (54)	160 (32)	57.81
Sweden	5	57 (82)	146 (7)	41.01	55 (89)	147 (3)	38.19	67 (63)	152 (22)	51.54	59 (91)	154 (4)	39.33	53 (69)	146 (24)	43.44
Turkey	2	139 (13)	154 (2)	91.45										167 (25)	192 (0)	86.98
North Macedonia	3	87 (39)	138 (12)	69.05	79 (43)	147 (25)	64.75							91 (49)	148 (8)	65.00
United States	5	55 (108)	174 (11)	33.74	81 (98)	183 (4)	45.25	189 (137)	370 (44)	57.98	84 (63)	158 (11)	57.14	50 (20)	78 (8)	71.43
Scotland	2	15 (92)	118 (11)	14.02	9 (95)	130 (26)	8.65									
Sweden (Grade 3)	1	60 (76)	144 (8)	44.12												
Canada (Ontario)	4	66 (117)	190 (7)	36.07	110 (60)	180 (10)	64.71	108 (74)	189 (7)	59.34	120 (59)	188 (9)	67.04			
Canada (Quebec)	5	39 (121)	182 (22)	24.38	87 (77)	185 (21)	53.05	114 (70)	190 (6)	61.96	67 (54)	127 (6)	55.37	46 (49)	112 (17)	48.42
Austria	4				73 (82)	158 (3)	47.10	80 (75)	158 (3)	51.61	71 (79)	150 (0)	47.33	76 (84)	160 (0)	47.50
Chinese Taipei	4				125 (25)	150 (0)	83.33	132 (14)	150 (4)	90.41	132 (18)	150 (0)	88.00	170 (14)	184 (0)	92.39
Denmark	4				56 (79)	145 (10)	41.48	113 (114)	232 (5)	49.78	109 (70)	185 (6)	60.89	96 (83)	197 (18)	53.63
Georgia	4				50 (87)	149 (12)	36.50	83 (83)	173 (7)	50.00	124 (68)	200 (8)	64.58	96 (91)	190 (3)	51.34
Indonesia	2				100 (66)	168 (2)	60.24	83 (70)	158 (5)	54.25						
Lithuania	4				58 (80)	146 (8)	42.03	13 (135)	154 (6)	8.78	52 (142)	195 (1)	26.80	38 (91)	190 (61)	29.46
Poland	4				57 (85)	148 (6)	40.14	35 (110)	150 (5)	24.14	49 (98)	148 (1)	33.33	40 (109)	150 (1)	26.85
Qatar	4				87 (15)	119 (17)	85.29	103 (53)	166 (10)	66.03	150 (65)	216 (1)	69.77	125 (132)	259 (2)	48.64
South Africa	3				259 (118)	397 (20)	68.70	55 (17)	92 (20)	76.39				226 (63)	321 (32)	78.20
Spain	4				73 (56)	152 (23)	56.59	166 (125)	312 (21)	57.04	325 (286)	629 (18)	53.19	222 (227)	452 (3)	49.44
Trinidad and Tobago	3				129 (14)	147 (4)	90.21	123 (19)	149 (7)	86.62	109 (23)	151 (19)	82.58			
England	4				56 (69)	148 (23)	44.80	66 (53)	129 (10)	55.46	78 (86)	170 (6)	47.56	76 (67)	162 (19)	53.15
Belgium (Flemish)	3				32 (94)	137 (11)	25.40				111 (22)	148 (15)	83.46	106 (18)	141 (17)	85.48
Belgium (French)	4				81 (46)	150 (23)	63.78	54 (61)	127 (12)	46.96	77 (72)	158 (9)	51.68	110 (33)	158 (15)	76.92
Canada (Alberta)	3				81 (67)	150 (2)	54.73	97 (44)	145 (4)	68.79				71 (29)	116 (16)	71.00
Canada (British Columbia)	2				71 (60)	148 (17)	54.20							94 (50)	179 (35)	65.28
Canada (Nova Scotia)	1				112 (78)	201 (11)	58.95									
Iceland (Grade 5)	1				15 (12)	35 (8)	55.56									
Norway (Grade 5)	1				36 (12)	66 (18)	75.00									
Azerbaijan, Republic of	3							143 (21)	169 (5)	87.20	133 (20)	170 (17)	86.93	107 (51)	184 (26)	67.72
Australia	3							164 (101)	280 (15)	61.89	143 (133)	286 (10)	51.81	132 (117)	281 (32)	53.01
Botswana	1							112 (31)	149 (6)	78.32						
Croatia	2							73 (64)	152 (15)	53.28				75 (70)	153 (8)	51.72
Finland	3							44 (92)	145 (9)	32.35	49 (101)	151 (1)	32.67	70 (148)	219 (1)	32.11
Honduras, Republic of	1							102 (36)	147 (9)	73.91						
Ireland	3							83 (61)	151 (7)	57.64	88 (57)	148 (3)	60.69	102 (44)	148 (2)	69.86
Malta	3							70 (19)	96 (7)	78.65	75 (20)	95 (0)	78.95	57 (19)	78 (2)	75.00
Oman	3							211 (65)	327 (51)	76.45	208 (85)	306 (13)	70.99	154 (59)	215 (2)	72.30
Portugal	3							81 (64)	148 (3)	55.86	143 (74)	218 (1)	65.90	101 (92)	196 (3)	52.33
Saudi Arabia	3							131 (34)	171 (6)	79.39	177 (24)	202 (1)	88.06	118 (22)	142 (2)	84.29
United Arab Emirates	3							262 (127)	458 (69)	67.35	293 (135)	468 (40)	68.46	259 (170)	663 (234)	60.37
Northern Ireland	3							61 (55)	136 (20)	52.59	62 (41)	134 (31)	60.19	85 (39)	143 (19)	68.55
Morocco (Grade 6)	1							139 (115)	278 (24)	54.72						
United Arab Emirates (Dubai)	3							77 (44)	138 (17)	63.64	100 (63)	174 (11)	61.35	63 (68)	190 (59)	48.09
United Arab Emirates (Abu Dhabi)	3							99 (49)	164 (16)	66.89	106 (36)	151 (9)	74.65	126 (65)	262 (71)	65.97
Malta (Maltese)	1							70 (18)	95 (7)	79.55						
Spain (Andalucia)	2							81 (59)	149 (9)	57.86	77 (69)	150 (4)	52.74			
Bahrain	2										108 (74)	182 (0)	59.34	104 (79)	186 (3)	56.83
Chile	1										96 (45)	154 (13)	68.09			
Kazakhstan	2										106 (63)	172 (3)	62.72	114 (147)	267 (6)	43.68
Macao SAR	2										52 (3)	57 (2)	94.55	57 (6)	63 (0)	90.48
Norway (4)	1										90 (61)	154 (3)	59.60			
South Africa (Eng/Afr)	1										63 (31)	125 (31)	67.02			
Argentina, Buenos Aires	1										76 (64)	150 (10)	54.29			
Russian Federation, Moscow	2										67 (83)	150 (0)	44.67	65 (109)	174 (0)	37.36
Spain, Madrid	1										77 (86)	168 (5)	47.24			
Albania	1													88 (81)	177 (8)	52.07
Brazil	1													132 (54)	187 (1)	70.97
Jordan	1													196 (20)	216 (0)	90.74

(*continued on next page*)

Table A1 (*continued*)

Country_name	Years_Info	*YEAR*														
		2001			2006			2011			2016			2021		
		T.S (N-T. S)	N (Mis)	P_TS	T.S (N-T. S)	N (Mis)	P_TS	T.S (N-T. S)	N (Mis)	P_TS	T.S (N-T. S)	N (Mis)	P_TS	T.S (N-T. S)	N (Mis)	P_TS
Kosovo	1													118 (27)	150 (5)	81.38
Montenegro	1													74 (63)	140 (3)	54.01
Serbia	1													88 (80)	169 (1)	52.38
Egypt	1													118 (71)	192 (3)	62.43
Uzbekistan	1													101 (77)	180 (2)	56.74
South Africa (Grade 6)	1													175 (51)	253 (27)	77.43
Canada (Newfoundland and Labrador)	1													56 (57)	133 (20)	49.56

Table A2
Descriptives of schools based on socio-economic status (high-SES and low-SES)

Country_name	*2001*			*2006*			*2011*			*2016*			*2021*		
	lowSES	*highSES*	*lowSES%*	*lowSES*	*highSES*	*lowSES%*	*lowSES*	*highSES*	*lowSES%*	*lowSES*	*highSES*	*lowSES%*	*lowSES*	*highSES*	*lowSES%*
Argentina	92	46	66.67												
Belize	67	53	55.83												
Bulgaria	50	120	29.41	44	99	30.77	45	102	30.61	43	110	28.1	33	118	21.85
Canda	61	311	16.4				209	902	18.81	156	770	16.85			
Colombia	111	36	75.51				99	51	66						
Cyprus	47	103	31.33										25	135	15.62
Czech Republic	32	109	22.7				19	158	10.73	9	148	5.73	10	186	5.1
France	22	123	15.17	36	133	21.3	43	131	24.71	54	109	33.13	49	135	26.63
Germany	48	163	22.75	86	319	21.23	44	153	22.34	49	159	23.56	96	156	38.1
Greece	71	74	48.97												
Hong Kong, SAR	42	105	28.57	31	113	21.53	55	77	41.67	50	88	36.23	42	102	29.17
Hungary	34	182	15.74	36	113	24.16	56	93	37.58	40	109	26.85	34	123	21.66
Iceland	26	107	19.55	31	97	24.22									
Iran, Islamic Republic of	75	109	40.76	89	147	37.71	108	136	44.26	104	167	38.38	82	136	37.61
Israel	34	113	23.13	43	106	28.86	54	98	35.53	35	124	22.01	59	135	30.41
Italy	9	175	4.89	13	137	8.67	34	168	16.83	23	126	15.44	22	142	13.41
Kuwait	26	109	19.26	26	123	17.45	45	88	33.83						
Latvia	30	110	21.43	16	131	10.88				8	142	5.33	13	143	8.33
Lithuania	27	119	18.49	23	123	15.75	42	112	27.27	18	177	9.23	71	119	37.37
Moldova	56	94	37.33	35	115	23.33									
Morocco	78	39	66.67	103	56	64.78	201	83	70.77	271	89	75.28	207	59	77.82
Netherlands	33	102	24.44	32	107	23.02	42	96	30.43	29	103	21.97	45	86	34.35
New Zealand	41	115	26.28	71	172	29.22	63	129	32.81	60	128	31.91	74	110	40.22
Norway	17	119	12.5	23	112	17.04	11	109	9.17	9	141	6	12	146	7.59
Romania	65	79	45.14	65	81	44.52	70	78	47.3						
Russian Federation	50	156	24.27	42	190	18.1	28	174	13.86	19	187	9.22	7	197	3.43
Singapore	15	181	7.65	11	167	6.18	6	170	3.41	8	169	4.52	5	178	2.73
Slovak Republic	35	115	23.33	23	144	13.77	32	165	16.24	17	203	7.73	21	148	12.43
Slovenia	8	140	5.41	17	128	11.72	33	162	16.92	38	122	23.75	40	120	25
Sweden	21	125	14.38	24	123	16.33	41	111	26.97	21	133	13.64	47	99	32.19
Turkey	96	58	62.34										92	100	47.92
North Macedonia	56	82	40.58	58	89	39.46							33	115	22.3
United States	71	103	40.8	78	105	42.62	192	178	51.89	95	63	60.13	40	38	51.28
England	26	105	19.85	50	98	33.78	48	81	37.21	37	133	21.76	46	116	28.4
Scotland	36	82	30.51	37	93	28.46									
Sweden (Grade 3)	22	122	15.28												
Canada (Ontario)	24	166	12.63	31	149	17.22	43	146	22.75	29	159	15.43			
Canada (Quebec)	37	145	20.33	39	146	21.08	41	149	21.58	25	102	19.69	33	79	29.46
Austria				15	143	9.49	21	137	13.29	27	123	18	31	129	19.38
Chinese Taipei				10	140	6.67	12	138	8	4	146	2.67	6	178	3.26
Denmark				13	132	8.97	16	216	6.9	19	166	10.27	29	168	14.72
Georgia				47	102	31.54	45	128	26.01	61	139	30.5	28	162	14.74
Indonesia				102	66	60.71	83	75	52.53						
				178	0	100									
Poland				27	121	18.24	22	128	14.67	17	131	11.49	9	141	6
Qatar				34	85	28.57	40	126	24.1	36	180	16.67	31	228	11.97
South Africa				302	95	76.07	55	37	59.78				258	63	80.37
Spain				27	125	17.76	59	253	18.91	114	515	18.12	53	399	11.73
Trinidad and Tobago				65	82	44.22	68	81	45.64	79	72	52.32			
Belgium (Flemish)				13	124	9.49				30	118	20.27	32	109	22.7
Belgium (French)				39	111	26	38	89	29.92	45	113	28.48	54	104	34.18
Canada (Alberta)				11	139	7.33	30	115	20.69				24	92	20.69
Canada (British Columbia)				27	121	18.24							46	133	25.7
Canada (Nova Scotia)				27	174	13.43									

(*continued on next page*)

Table A2 (*continued*)

Country_name	*2001*			*2006*			*2011*			*2016*			*2021*		
	lowSES	*highSES*	*lowSES%*	*lowSES*	*highSES*	*lowSES%*	*lowSES*	*highSES*	*lowSES%*	*lowSES*	*highSES*	*lowSES%*	*lowSES*	*highSES*	*lowSES%*
Iceland (Grade 5)				15	20	42.86									
Norway (Grade 5)				21	45	31.82									
Azerbaijan, Republic of							65	104	38.46	97	73	57.06	106	78	57.61
Australia							64	216	22.86	65	221	22.73	77	204	27.4
Botswana							52	97	34.9						
Croatia							16	136	10.53				15	138	9.8
Finland							18	127	12.41	8	143	5.3	11	208	5.02
Honduras, Republic of							110	37	74.83						
Ireland							53	98	35.1	41	107	27.7	40	108	27.03
Malta							19	77	19.79	5	90	5.26	7	71	8.97
Oman							108	219	33.03	43	263	14.05	31	184	14.42
Portugal							36	112	24.32	64	154	29.36	39	157	19.9
Saudi Arabia							36	135	21.05	43	159	21.29	18	124	12.68
United Arab Emirates							148	310	32.31	168	300	35.9	288	375	43.44
Northern Ireland							38	98	27.94	51	83	38.06	44	99	30.77
Morocco (Grade 6)							199	79	71.58						
United Arab Emirates (Dubai)							40	98	28.99	49	125	28.16	70	120	36.84
United Arab Emirates (Abu Dhabi)							56	108	34.15	57	94	37.75	97	165	37.02
Malta (Maltese)							19	76	20						
Spain (Andalucia)							30	119	20.13	30	120	20			
Bahrain										41	141	22.53	80	106	43.01
Chile										82	72	53.25			
Kazakhstan										7	165	4.07	11	256	4.12
Macao SAR										14	43	24.56	17	46	26.98
Norway (4)										9	145	5.84			
South Africa (Eng/Afr)										96	29	76.8			
Argentina, Buenos Aires										78	72	52			
Russian Federation, Moscow										6	144	4	1	173	.57
Spain, Madrid										37	131	22.02			
Albania													41	136	23.16
Brazil													87	100	46.52
Jordan													98	118	45.37
Kosovo													35	115	23.33
Montenegro													42	98	30
Serbia													15	154	8.88
Egypt													81	111	42.19
Uzbekistan													18	162	10
South Africa (Grade 6)													181	72	71.54
Canada (Newfoundland and Labrador)													31	102	23.31

Table A3
Descriptives of schools based on location (rural and urban)

Country_name	School location	2001	2006	2011	2016	2021
Argentina	rural	76				
Argentina	urban	39				
Belize	rural	33				
Belize	urban	1				
Bulgaria	rural	73	104	106	104	102
Bulgaria	urban	55	34	40	49	48
Canda	rural	225		716	556	
Canda	urban	112		356	329	
Colombia	rural	45		86		
Colombia	urban	53		60		
Cyprus	rural	41				133
Cyprus	urban	17				27
Czech Republic	rural	91		144	133	160
Czech Republic	urban	22		30	24	34
France	rural	67	138	150	131	148
France	urban	16	21	16	25	25
Germany	rural	90	273	138	129	139
Germany	urban	58	114	47	60	61
Greece	rural	71				
Greece	urban	38				
Hungary	rural	75	117	111	105	107
Hungary	urban	45	27	33	40	38
Iceland	rural	62	100			
Iceland	urban	20	17			
Iran, Islamic Republic of	rural	34	144	136	134	111
Iran, Islamic Republic of	urban	72	90	100	127	101
Israel	rural	69	110	106	109	127

(*continued on next page*)

Table A3 (*continued*)

Country_name	School location	2001	2006	2011	2016	2021
Israel	urban	39	30	30	49	44
Italy	rural	146	127	164	121	126
Italy	urban	33	22	32	17	35
Kuwait	rural	70	123	100		
Kuwait	urban	12	7	10		
Latvia	rural	47	108		104	106
Latvia	urban	42	37		46	43
Lithuania	rural	58	104	98	118	82
Lithuania	urban	56	40	53	77	48
Moldova	rural	50	122			
Moldova	urban	26	20			
Morocco	rural	21	84	152	260	172
Morocco	urban	39	25	91	80	76
Netherlands	rural	88	89	99	90	84
Netherlands	urban	25	27	15	23	17
New Zealand	rural	70	147	98	91	80
New Zealand	urban	58	78	79	84	60
Norway	rural	67	102	92	121	132
Norway	urban	25	22	23	25	23
Romania	rural	47	114	115		
Romania	urban	34	29	32		
Russian Federation	rural	45	143	107	104	101
Russian Federation	urban	64	89	95	102	99
Singapore	urban	196	178	176	173	181
Slovak Republic	rural	133	155	174	193	144
Slovak Republic	urban	12	11	19	27	21
Slovenia	rural	102	117	169	139	114
Slovenia	urban	19	23	21	13	17
Sweden	rural	89	114	111	103	82
Sweden	urban	28	29	24	47	41
Turkey	rural	34				61
Turkey	urban	84				127
North Macedonia	rural	51	109			123
North Macedonia	urban	34	18			18
United States	rural	89	115	219	96	46
United States	urban	65	61	110	49	23
England	rural	56	79	66	100	81
England	urban	35	40	44	59	59
Scotland	rural	58	86			
Scotland	urban	22	14			
Sweden (Grade 3)	rural	88				
Sweden (Grade 3)	urban	26				
Canada (Ontario)	rural	97	88	80	69	
Canada (Ontario)	urban	77	83	100	110	
Canada (Quebec)	rural	128	130	111	62	59
Canada (Quebec)	urban	35	34	74	59	35
Austria	rural		122	120	109	112
Austria	urban		34	37	41	48
Chinese Taipei	rural		71	64	53	57
Chinese Taipei	urban		71	82	97	127
Denmark	rural		127	200	156	151
Denmark	urban		10	30	18	29
Georgia	rural		103	113	112	98
Georgia	urban		38	54	85	88
Indonesia	rural		143	42		
Indonesia	urban		21	99		
Poland	rural		114	113	109	108
Poland	urban		34	35	39	38
Qatar	rural		84	111	132	156
Qatar	urban		8	44	78	99
South Africa	rural		346	51		224
South Africa	urban		35	19		44
Spain	rural		94	203	344	299
Spain	urban		42	94	274	147
Trinidad and Tobago	rural		137	135	124	
Trinidad and Tobago	urban		3	6	6	
Belgium (Flemish)	rural		115		113	116
Belgium (Flemish)	urban		11		21	9
Belgium (French)	rural		102	91	123	111
Belgium (French)	urban		21	18	22	25
Canada (Alberta)	rural		80	76		45
Canada (Alberta)	urban		68	64		55
Canada (British Columbia)	rural		72			75
Canada (British Columbia)	urban		57			69
Canada (Nova Scotia)	rural		163			
Canada (Nova Scotia)	urban		28			

(*continued on next page*)

Table A3 (*continued*)

Country_name	School location	2001	2006	2011	2016	2021
Iceland (Grade 5)	rural		19			
Iceland (Grade 5)	urban		7			
Norway (Grade 5)	rural		41			
Norway (Grade 5)	urban		8			
Azerbaijan, Republic of	rural			139	132	146
Azerbaijan, Republic of	urban			28	28	28
Australia	rural			145	143	138
Australia	urban			120	130	112
Botswana	rural			138		
Botswana	urban			5		
Croatia	rural			129		110
Croatia	urban			23		36
Finland	rural			97	105	150
Finland	urban			43	46	66
Honduras, Republic of	rural			117		
Honduras, Republic of	urban			25		
Hong Kong, SAR	rural			18	12	15
Hong Kong, SAR	urban			89	117	121
Ireland	rural			121	128	121
Ireland	urban			24	16	25
Malta	rural			92	95	76
Oman	rural			271	254	158
Oman	urban			10	35	31
Portugal	rural			123	193	150
Portugal	urban			20	24	42
Saudi Arabia	rural			72	98	46
Saudi Arabia	urban			94	101	91
United Arab Emirates	rural			222	208	177
United Arab Emirates	urban			178	215	250
Northern Ireland	rural			86	78	91
Northern Ireland	urban			24	21	30
Morocco (Grade 6)	rural			153		
Morocco (Grade 6)	urban			82		
United Arab Emirates (Dubai)	rural			51	55	38
United Arab Emirates (Dubai)	urban			71	105	92
United Arab Emirates (Abu Dhabi)	rural			90	73	87
United Arab Emirates (Abu Dhabi)	urban			58	65	104
Malta (Maltese)	rural			91		
Spain (Andalucia)	rural			97	95	
Spain (Andalucia)	urban			43	53	
Bahrain	rural				143	139
Bahrain	urban				30	32
Chile	rural				50	
Chile	urban				91	
Kazakhstan	rural				119	160
Kazakhstan	urban				53	100
Macao SAR	rural				14	7
Macao SAR	urban				42	56
Norway (4)	rural				125	
Norway (4)	urban				25	
South Africa (Eng/Afr)	rural				71	
South Africa (Eng/Afr)	urban				20	
Argentina, Buenos Aires	urban				143	
Russian Federation, Moscow	rural				4	4
Russian Federation, Moscow	urban				146	167
Spain, Madrid	rural				59	
Spain, Madrid	urban				104	
Albania	rural					119
Albania	urban					45
Brazil	rural					85
Brazil	urban					91
Jordan	rural					146
Jordan	urban					58
Kosovo	rural					123
Kosovo	urban					14
Montenegro	rural					122
Montenegro	urban					12
Serbia	rural					117
Serbia	urban					51
Egypt	rural					122
Egypt	urban					51
Uzbekistan	rural					151
Uzbekistan	urban					26
South Africa (Grade 6)	rural					165
South Africa (Grade 6)	urban					44
Canada (Newfoundland and Labrador)	rural					99
Canada (Newfoundland and Labrador)	urban					14

Sensitivity Analysis.

Appendix Table A4
Fixed-Effects Model Results Treating Principals' Concern over Teacher Shortage and School Socioeconomic Status (SES) as Continuous Variables

Variable	Estimate	Std. Error	t-value	Pr(>|t|)	Significance
Intercept (2001)	52,8	3,42	15,4	<.001	***
Year2006	6,95	3,12	2,23	.027	*
Year2011	9,46	3,06	3,09	.002	**
Year2016	7,12	3,08	2,31	.021	*
Year2021	5,41	3,01	1,8	.073	
SES (continuous)	−1,84	1,17	−1,57	.117	
Year2006 × SES	−0,72	1,48	−0,49	.625	
Year2011 × SES	−2,31	1,43	−1,61	.108	
Year2016 × SES	−0,95	1,41	−0,68	.498	
Year2021 × SES	0,61	1,38	0,44	.661	

Appendix Table A5
Fixed-Effects Model Results Treating Principals' Concern over Teacher Shortage and School Location as Continuous Variables

Variable	Estimate	Std. Error	t-value	Pr(>|t|)	Significance
Intercept (2001)	47,6	3,85	12,4	<.001	***
Year2006	5,58	3,61	1,55	.122	
Year2011	9,42	3,54	2,66	.008	**
Year2016	9,77	3,58	2,73	.007	**
Year2021	7,69	3,48	2,21	.028	*
Location (continuous)	0,84	3,65	0,23	.819	
Year2006 × Location	−1,51	4,89	−0,31	.760	
Year2011 × Location	−2,45	4,68	−0,52	.603	
Year2016 × Location	−4,16	4,68	−0,89	.376	
Year2021 × Location	−3,32	4,56	−0,73	.468	

Data availability

secondary data which is publicly available

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