# From Population Growth to Demographic Scarcity: Emerging Challenges to Global Primary Education Provision in the Twenty-first Century*

Emily Hannum, Jeonghyeok Kim, and Fan Wang†

July 13, 2023

**Abstract**

Global population trends are changing the nature of what might be termed the "demographic challenge" to primary educational systems. The traditional demographic challenge, and one that continues in some countries, is population expansion and ever-increasing child cohort sizes. An emerging regime of declining and sparse child cohorts poses the challenge of how to maintain a system that reaches dispersed, scarce school-age populations. The answers to the traditional challenge were to increase the number of schools and teachers. A key policy response to the emerging challenge has been to consolidate—a strategy that hits sparse rural and dense urban communities very differently. Primary school consolidation has been a significant policy response to changing demographics in high income, low fertility countries, but is also emerging in middle income countries with large rural populations.

In this paper, we first consider the relevance of demographic scarcity to primary school systems globally. Second, equipped with a unique new panel dataset on cross-country counts of students, teachers, and schools, we focus on illustrative cases—East Asia and Western Europe—which are at the forefront of both demographic pressures and policy responses. Key economies in East Asia and Western Europe have uniformly increased the number of teachers in recent decades despite countervailing demographic forces. In contrast, while China and Japan along with Western European countries have shut down substantial shares of schools in recent decades, Korea and Taiwan have built more. Third, focusing in on Korea, the country with the lowest fertility rates globally, we examine within-country school resources changes from 1980 to 2020. Korea has substantially reduced the number of teachers and schools in rural areas while increasing the number of teachers and schools serving urban areas. We document and discuss large shifts in Korean rural consolidation policy from large-scale closure prior to year 2000 to stabilization afterwards.

**JEL**: J15, I24, O15
**Keywords**: Demographics, Pupil to Teacher Ratio, School Enrollment Size, Western Europe, East Asia, Korea

*This latest version of this paper is available at this link: GlobalPrimaryDemoEdu_HKW.

†Emily Hannum: Department of Sociology and Population Studies Center, University of Pennsylvania, 3718 Locust Walk, Philadelphia, Pennsylvania, USA (hannumem@sas.upenn.edu); Jeonghyeok Kim: Department of Economics, University of Houston, Houston, Texas, USA (jkim124@uh.edu); Fan Wang: Department of Economics, University of Houston, Houston, Texas, USA (fwang26@uh.edu). We gratefully acknowledge support from Penn's University Research Foundation and School of Arts and Sciences Research Opportunity Grant Programs. Data and statistical programs used by the paper is available at https://fanwangecon.github.io/PrjCompPPTS.

## Introduction

Global population trends are changing the nature of what might be termed the "demographic challenge" to primary educational systems. The traditional demographic challenge, and one that continues in some countries, is one of population expansion. A regime of ever-increasing child cohorts places intense pressures on governments to expand school access even to maintain the status quo in enrollment rates (Gaigbe-Togbe et al. 2022; Sánchez et al. 2023). The two possible answers to the traditional challenge were to build more schools or to increase the size of existing schools, to reach more rural and marginalized communities. In contrast, an emerging regime of sparse and declining child cohorts—demographic scarcity associated with some combination of age structure effects, fertility decline, or urbanization and hollowing out of rural communities—poses the challenge of desigining systems that can serve dispersed, scarce school age populations (OECD and European Commission 2021). A key answer to the emerging challenge of demographic scarcity has been to consolidate—a strategy that hits sparse rural and dense urban communities very differently.

Research in economics and sociology documents recent and pending demographic shifts (Bloom and Luca 2016; Crimmins and Zhang 2019; Settersten and Angel 2011), investigates the effects of decreasing youth population on labor market structures and economic growth (Bloom, Canning, and Sevilla 2001; Korenman and Neumark 1997; Mason et al. 2009), and forecasts the implications of elongating population pyramids on inter-generational-inequality (Dolls et al. 2019; Prettner 2013; Weizsäcker 1996). However, to the best of our knowledge, there are not prior global or regional studies investigating the relationship between demographic changes in the school age population and school system responses. Further, we have not found analyses of global implications of changing school-age populations for number of students per school and per teacher.

School enrollment size and the teacher count are two key dimensions of educational resource provisions. Existing research has focused on the effects of school enrollment or size (Leithwood and Jantzi 2009) as well as effects of the pupil to teacher ratio or class size (Filges, Sonne-Schmidt, and Nielsen 2018) on student outcomes. While variations across space and changes

over time in population size has been recognized as instruments to identify the effects of school enrollment size (Kuziemko 2006), class size (Angrist et al. 2019; Choi and Kang 2007; Hoxby 2000), and school resources (Das et al. 2013) on student outcomes, the literature has not studied the global effects of changing school-age population sizes on the number of students per school and per teacher. Instead, the results of the school and class size "effects" literature has been applied to consider the optimal allocation of resources holding existing population patterns fixed (Barrett et al. 2019).

With data availability in mind, we have a limited scope–we describe where countries are on in terms of demographic trajectories in the child population, and we investigate how systems are responding to demographic trajectories in terms of two indicators of primary school provision that are more accessible: teacher and school counts. Leveraging differing degrees of data availability at different levels of aggregation, we conduct global, regional, and within country analysis. Globally, we investigate child population changes and changes in the provision of teachers. We then focus on responses in terms of provision of schools and teachers in two low-fertility regions–Western Europe and Eastern Asia, to look at system response. Finally, we focus in on the case of South Korea, at the vanguard of low fertility, to illustrate some of the geospatial complexities that can emerge in the context of child population decline.

We first document global patterns of child population changes where higher-income economies are further ahead along the youth population hump and countries are situated along a path of increasing, plateauing, and decreasing child population. Globally, we compare changes in child population to changes in the number of primary-school teachers. We find that most countries in recent decades have experienced substantial increases in the number of teachers. This has led to substantial reductions in the pupil to teacher ratio in many countries, especially those experiencing reductions in school age population. While researchers have long been aware of the challenges associated with expanding access to education in the context of a growing child population (King and Hill 1997; Lewin 2009; Spaull and Kotze 2015), we show that an increasingly urgent issue is the potential contraction pressure exerted on primary education systems due to current or incipient school age population decline.

We then focus on illustrative cases—East Asia and Western Europe—which are at the

forefront of both demographic pressures and policy responses. We compile for the first time a cross-national panel dataset with data on the number of primary schools, teachers, and students.[1] The economies we focus on are China, Korea, Japan, and Taiwan as well as Austria, Germany, France, Switzerland, and the Netherland. All of these economies are at the forefront of declining fertility, however, despite similar fertility rates, youth population reduction has been much more dramatic in East Asia compared to Western European countries, due to immigration patterns in Western Europe. All of these economies have increased the number of teachers despite the substantial decline in school age population in East Asia and smaller declines in Western Europe. However, the response in terms of the number of schools varies significantly across countries. In East Asia, China and Japan have adopted large-scale school closures in response to declining youth populations, but Korea and Taiwan have maintained the number of schools. In contrast, some Western European countries have undergone substantial school closures in the context of more limited reduction in overall youth population levels.

Lastly, we examine school resources within Korea, which is the country with the lowest fertility rate in the world, and is the one that has experienced the largest reductions in youth population in East Asia and Western Europe. Korea also has consistent and long-horizon datasets on the number of schools, teachers, and students in each province in more and less urbanized locations. We find that Korea embarked on a rapid campaign of school closure, especially in less urban areas prior to 2000, but public pressures led to a dramatic halt to the policy, leading to a recovery in the number of primary schools in recent years.

## Data and Methods

We construct a novel dataset by combining multiple sources of data. First, we use the World Development Indicators from the World Bank spanning from 1960-2021 to examine global trends in the school-age population and educational system responses.[2] We use child population

[1] We use official statistical records from large economies in East Asia and Western Europe and consider student, teacher, and school counts.

[2] World Development Indicators is the World Bank's premier compilation of cross-country comparable data on development containing 217 economies and more than 40 country groups, with data for various indicators going back more than 50 years.

from ages 0 to 14 as the the measure for population changes,[3] and the percentage changes in the number of primary teachers as the measure for shifts in teacher resources. We use country-specific statistics and construct time-frames to maximize the number of countries with comparable data for changes over time.[4]

Second, we gather official statistical records pertaining to school, teacher, and student counts on a yearly basis from the following economies in East Asia and Western Europe: China, Japan, Korea, Taiwan, Austria, Germany, France, Netherlands, and Switzerland.[5] In East Asia, the Chinese data covers years from 1949-2021 and is sourced from the National Bureau of Statistics. The Japanese data is obtained from Statistics of Japan and covers years from 1948-2022. Korean data is sourced from the Korean Educational Statistics Service covering years from 1965 to 2021. The Taiwanese data is obtained from the Ministry of Education and spans from 1976 to 2021.

For Western Europe, Austrian data is taken from Statistics Austria covering years from 1923 to 2020. German data is obtained from the Federal Ministry of Education and Research and covers post-unification data from 1992 to 2020. French data is sourced from the Statistical benchmarks and references (RERS) as well as the Ministry of National Education, and covers years from 1980 to 2021. The data for the Netherlands is sourced from Statistics Netherlands (CBS) and covers the period from 1990 to 2021. As for Switzerland, the data is obtained from the Federal Statistics Office and covers the years from 1864 to 2020 with a gap in the available data between years.[6]

Third, the Korean data is categorized into two sections, metropolitan and non-metropolitan areas. Metropolitan areas include the capital area (Seoul, Incheon, Gyeong-gi) and metropolitan cities (Busan, Daegu, Daejeon, Ulsan, Sejong). Non-metropolitan areas encompass all other areas that are not included in the metropolitan areas (Gangwon, Chungbuk, Chungnam, Jeonbuk,

[3] Primary school age differs across countries, we use population between ages 0 to 14 as a uniform demographic unit to ease international comparisons.

[4] We also use aggregate regional statistics constructed by World Bank for Sub-Saharan Africa, Middle East and North Africa, Latin America, North America, South Asia, Euro area, and East Asia and Pacific.

[5] According to the "Standard Country or Area Codes for Statistical Use" published by the United Nations, the countries in Western Europe include Austria, France, Germany, Liechtenstein, Luxembourg, Monaco, the Netherlands, and Switzerland. We focus on countries with a population of at least one million with the exception of Belgium due to data availability.

[6] For more detail of data source, see Appendix B. We've also set up a data page where other researcher can access translated data in English, along with its source, to easily calculate changes in educational inputs and school age population over time.

Jeonnam, Gyeongbuk, Gyeongnam, Jeju).[7]

Combining the data, we calculate percentage changes in the number of schools, teachers, students, and youth populations. The percentage change in educational input is defined as follows:

$$\%ChangeEducInput_{it} = \frac{EducInput_{i,t+\tau} - EducInput_{it}}{EducInput_{it}} \times 100, \quad (1)$$

where $EducInput_{it}$ is the educational input $i$ in year $t$. We define the percentage change in school age population in the same manner. We also calculate the pupil-teacher and pupil-school ratios to observe absolute level changes in school resources.

## Results

**Global: Population** Using forty years of global, country-level data on school age populations, defined for simplicity as populations ages 0 to 14, we identify three types of regions: regions where the school age population has been increasing steadily (Africa and the Middle East), regions where school age populations have recently peaked and beginning to trend downward (the Americas and South Asia), and regions that are in longer-term decline (East Asia and Europe). Figure 1 contains panels for these three regions and shows trends in the school age population between 1960 and 2020, expressed as percentage differences relative to a reference year set to 2020.[8] Sub-Saharan Africa and the Middle East and North Africa have seen increases of 83-158% in the school age population between 1960 and 2020. Latin America, North America, and South Asia plateaued around 2000-2010, while the Euro area and East Asia and Pacific peaked around 1970 and have since been declining.

[7] It is worth noting that during the period of analysis, multiple metropolitan cities gained independence from their respective provinces and were designated as metropolitan cities. For example, in 1982, Daegu became a metropolitan city separate from Gyeongbuk. The designation of a metropolitan city leads to a sudden increase in counts in the area, and a corresponding decrease in the province from which it was originally a part. For instance of Daegu, the school count is 0 before 1982 and 86 in 1982. To account for this, I assign the count number from the metropolitan area in the year of independence to the years before the designation and subtract it from the original province before the designation. That is, my analysis conservatively measures the increase in counts in metropolitan areas and the decrease in non-metropolitan areas, considering designated areas are growing faster than other areas.

[8] For raw number changes in school age population by region, see Appendix Figure A.1.

**Global: Population and Teachers** We turn to the educational response to global school age population change, with attention to the implications of demographic context on educational quality.[9] We focus on teacher percentage changes, one of the only indicators linked to quality that exists over time at the national level. Figure 2 shows the percentage change in the number of teachers plotted against the percentage change in school aged population, for the two periods 1981–2000 and 2000–2020.

From 1981 to 2020, most African countries—marked with red circles in Figure 2—have seen their primary age population steadily increase. In response to this, in nearly all African countries, the number of primary school teachers increased. In the first two decades, we observe that half of the African countries are below 45-degree line—the increase in school age population was faster than the increase in teacher count. Over time, the rate of increase in the school-age population has slowed down, while the rate of increase in the number of teachers has accelerated. Between 2000 and 2020, in almost all African countries, the growth rate of primary school teachers has surpassed the rate of population expansion, leading to decrease in pupil to teacher ratio.

Countries in the Americas and South Asia—highlighted with blue triangles in Figure 2—largely experienced increases in primary age population in the 1980s and 1990s, but many more have begun experiencing primary age population contractions in the more recent two decades. Despite this, the number of teachers has consistently increased throughout both periods, although at a slower rate over time.

East Asian and European countries—highlighted with green squares in Figure 2—have experienced striking population reductions in the past four decades. In the 1980s and 1990s, this was largely accompanied by continued expansion of the number of teachers, leading to a rapid fall in the pupil to teacher ratio. In the more recent two decades, however, more countries have begun to reduce the number of teachers.

Treating maintaining or improving absolute pupil-teacher ratios as a very rough proxy for success in educational response to demographic context, the challenges were daunting in African countries through the late 1990s (UNESCO Institute for Statistics 2019). In the past 2

[9] It is also worth noting that, to the best of our knowledge, there is no comprehensive data set that provides information on schools at the country level while student and teacher information is readily available from multiple sources such as the World Bank Open Data, UNESCO Institute for Statistics, OECD Data, and Eurostat.

decades, many more countries including African countries experienced reductions in pupil to teacher ratios, regardless of patterns of population changes. Figure 2 suggests a high degree of heterogeneity over time and across regions in the nature and scope of demographic pressures on school systems. But overall, Figure 2 shows a substantial leftward shift across all regions and countries: some countries experience a deceleration of school-age population increase, some countries move from increases to stagnation, and other countries accelerate along the path of school-age population contraction. This finding highlights the importance of studying countries at the forefront of demographic changes.

**Western Europe and East Asia: Population, Teachers, and Schools** Low fertility and declining school age cohorts are increasingly relevant for educational planners for many countries. East Asia and Europe are at the forefront of these patterns. Here, we focus on a selection of economies in East Asia and Western Europe for which governmental statistic permit investigation of how the number of schools and teachers responds to youth population changes. Figures 3 and 4 presents the percentage changes in the number of primary schools, teachers, and students in East Asian and Western European countries.[10]

One trend that stands out is the persistent decline in the number of students since 1980, with the exception of recent increases in Switzerland, which might be linked to migration. East Asia, in particular, has experienced a very pronounced decline, with primary school student numbers in Korea and Taiwan decreasing by roughly 50% over the last two decades. Japan and China also experienced large reductions, with primary school student numbers falling by about 35% over the same period. Tracing further back, compared to 1980, primary school student numbers in Korea, Taiwan, and Japan declined by between 90% to 110%.

In terms of teachers, China, Korea, and Taiwan increased teacher counts by 20-40% since 1980. Japan and Taiwan have decreased teacher counts in the recent decades, but the rates of decline have been slower than the rates of student population reductions. In all four economies, the pupil-teacher ratios have steadily declined and converged to between 10-20 by 2020. This is in sharp contrast to the large gaps in pupil-teacher ratio in the 1970s, when the ratio of Korea

[10] For percentage change in school and teacher counts by decade from 1961-2020 and elasticities of school and teacher count with respect to youth population, see Appendix Table A.1. For raw number changes in terms of pupil to teacher and pupil to school ratio by decade, see Appendix Table A.2.

was almost 60, Taiwan approximately 40, China around 35, and Japan 25. Western European countries also show similar increasing patterns for the number of teachers, and declining pupil-teacher ratios, which have also converged to 10-20 by 2020.

While the trend in teacher numbers appears to be universal, the response in the number of schools varies significantly across economies in East Asia. China and Japan have closed a considerable number of primary schools over the years, from 1980 closing about 80% in China and 30% in Japan. In contrast, Taiwan has built more schools and the school count increased by 10% since 1980. Korea shows stark changes over time. The number of schools decreased by 20% from 1981-2000 but increased by 15% since 2000. The pupil-school ratio shows that countries converge to similar levels though they have very different patterns in percentage changes. In Western economies, however, the trend is toward closing schools. Austria, Germany, France, and the Netherlands have decreased more than 10% of primary schools since 2000. The pupil-school ratio is more stable than in East Asian countries.

Jointly, Figures 3 and 4 show that school-system resource policy responses, in terms of teachers and schools, have been heterogeneous across countries and time. Despite their heterogeneities, by 2020, we see three emerging models. The China model of large school and small class. The Korea, Japan and Taiwan model of medium-size school and small class. And the European model of small school and small class. These show different response paradigms exhibited by different countries that are at the forefront of declining school-age populations.

**Korea: Population, Teachers, and Schools in Metropolitan and non-Metropolitan Areas**

One country at the forefront of school-age population decline is South Korea, which has a reported total fertility rate of .78 in 2022—the lowest in the world (Kim 2023). The case of South Korea illustrates the new geospatial challenges in educational planning in the context of ultra-low fertility. In Figure 5, we present the percentage changes in students, teachers, schools, and pupil-teacher and pupil-school ratios in metropolitan and non-metropolitan areas separately from 1971-2020.[11] The number of primary students in Korea decreased by 120 percent from 1971 to 2020. This decline has been consistent throughout the years. The overall reduction is

[11] For changes in students, teachers, and schools by each metropolitan city and non-metropolitan province, see Appendix Figure A.4.

driven by reductions in non-metropolitan areas (300%) while metropolitan areas experience 30% reduction.

From 1981 to 2000, non-metropolitan teachers decreased by 19%, and primary schools decreased by 57%. After the year 2000, there was a dramatic shift in this trend in non-metropolitan areas. The number of non-metropolitan primary schools remained stable, and there was an increase in primary teachers by 20%. In the meantime, pupil-teacher and pupil-school ratios declined from 50 to 12 and from 690 to 280 respectively. On the other hand, in metropolitan areas experience continuous expansion in both teacher and school counts. From 1971 to 2020, the number of teachers increased by 77%, and the number of schools increased by 65%. The pupil-teacher ratio decreased dramatically, falling from 68 to around 15 by 2020, and pupil-school ratio declined from 1900 to 590.

In Korea, the pressure for population reduction was dramatically greater in rural areas, especially in the 1980s and 1990s. These pressure led to the large-scale reductions in both rural teachers and schools, but eventually the government had to reverse course. The policy shift in 2000 was influenced by resistance from local communities. Demographic and financial pressures led to a large reduction in non-metropolitan primary schools prior to 2000 (Ministry of Education 2016). The resulting wave of school closures in the 1990s causes public outcry given the perceived negative effects of closures on the local communities. Resistance from the local communities halted additional school closures in non-metropolitan after 2000 (Lee, Kim, and Ma 2010).

## Discussion

This paper has sought to describe the changing demographic context of primary school provision globally, with attention to the implications of and emerging trend of school age demographic scarcity. We would like to highlight three main observations. First, across countries and regions, demographic pressures have been changing globally in ways that carry potentially disequalizing implications for educational quality. In the period under study, growing child cohorts remained a daunting challenge in countries in Sub-Saharan Africa. There, ever-increasing cohorts of school-aged children placed pressures to expand capacity on the world region with the highest

rates of educational exclusion (UNESCO Institute for Statistics 2019). At the other demographic extreme, Europe and Eastern Asia are experiencing sharp drops in school-aged populations. This trend reverses expansionary pressures on school systems and, in principle, could allow for higher quality educational experiences via shifts toward smaller pupil-teacher ratios. However, this trend also places pressure on primary education systems to potentially close schools in areas with dwindling population.

Second, within countries, new considerations around spatial inequalities and school system design are emerging in the context of depopulation and demographic scarcity. For example, in Korea, schools in metropolitan areas have grown and those in non-metropolitan areas have declined sharply, even though the number of students in both kinds of areas have been declining. In China, rural children in poorer parts of the country have been highly susceptible to the policy response of consolidation and boarding at schools (Hannum and Wang 2022), for children as young as primary school age. A recent OECD report highlights that rural schools in OECD countries are facing smaller schools and class sizes as a result of declining student numbers, and suggests that preparing rural schools for the future will require rethinking of traditional approaches to education provision in ways that go beyond relocating rural students to larger, more distant schools (OECD 2021).[12]

Finally, studying the diverse response strategies of countries at the forefront of school-age demographic decline is important, as larger numbers of countries face the same phenomenon. We have shown that national responses to demographic decline are heterogeneous across systems. While improved pupil-teacher ratios are relatively common as expansionary pressures have eased over the long term, school systems differ dramatically in the degree to which they are changing the numbers of schools in relation to population decline. These findings highlight the potential value in study of divergent policy responses to common, emerging demographic changes.

[12] Further complicating the geospatial considerations, in some countries, immigration into certain parts of the country may buffer the effects of low fertility on population structures, and in many countries internal migration may change the spatial distribution of school age children substantially at subnational levels.

## References for Extended Abstract


Angrist, Joshua D., Victor Lavy, Jetson Leder-Luis, and Adi Shany. 2019. "Maimonides' Rule Redux." *American Economic Review: Insights* 1, no. 3 (December): 309–324. https://doi.org/10.1257/aeri.20180120.

Barrett, Peter, Alberto Treves, Tigran Shmis, and Diego Ambasz. 2019. *The Impact of School Infrastructure on Learning: A Synthesis of the Evidence.* World Bank Publications, February 4, 2019.

Bloom, D.E., and D.L. Luca. 2016. "The Global Demography of Aging." In *Handbook of the Economics of Population Aging,* 1:3–56. Elsevier. https://doi.org/10.1016/bs.hespa.2016.06.002.

Bloom, David, David Canning, and Jaypee Sevilla. 2001. *Economic Growth and the Demographic Transition.* w8685. Cambridge, MA: National Bureau of Economic Research, December. https://doi.org/10.3386/w8685.

Choi, Jun-ryeol, and Dae-jung Kang. 2007. "Analysis of the Current Status of Consolidation and Closure of Small Rural Schools and Improvement Plans." *Policy Report from Ministry of Education,* https://dl.nanet.go.kr/SearchDetailView.do?cn=MONO1200805795#none.

Crimmins, Eileen M., and Yuan S. Zhang. 2019. "Aging Populations, Mortality, and Life Expectancy." *Annual Review of Sociology* 45, no. 1 (July 30, 2019): 69–89. https://doi.org/10.1146/annurev-soc-073117-041351.

Das, Jishnu, Stefan Dercon, James Habyarimana, Pramila Krishnan, Karthik Muralidharan, and Venkatesh Sundararaman. 2013. "School Inputs, Household Substitution, and Test Scores." *American Economic Journal: Applied Economics* 5, no. 2 (April): 29–57. https://doi.org/10.1257/app.5.2.29.

Dolls, Mathias, Karina Doorley, Alari Paulus, Hilmar Schneider, and Eric Sommer. 2019. "Demographic Change and the European Income Distribution." *The Journal of Economic Inequality* 17, no. 3 (September): 337–357. https://doi.org/10.1007/s10888-019-09411-z.

Filges, Trine, Christoffer Scavenius Sonne-Schmidt, and Bjørn Christian Viinholt Nielsen. 2018. "Small Class Sizes for Improving Student Achievement in Primary and Secondary Schools: A Systematic Review." *Campbell Systematic Reviews* 14 (1): 1–107. https://doi.org/10.4073/csr.2018.10.

Gaigbe-Togbe, Victor, Lina Bassarsky, Danan Gu, Thomas Spoorenberg, and Lubov Zeifman. 2022. *World Population Prospects 2022: Summary of Results.* Technical report UN DESA/POP/2022/TR/NO. 3. New York, NY: United Nations Department of Economic and Social Affairs, Population Division. https://www.un.org/development/desa/pd/sites/www.un.org.development.desa.pd/files/wpp2022_summary_of_results.pdf.

Hannum, Emily, and Fan Wang. 2022. "Fewer, Better Pathways for All? Intersectional Impacts of Rural School Consolidation in China's Minority Regions." *World Development* 151 (March): 105734. https://doi.org/10.1016/j.worlddev.2021.105734.

Hoxby, Caroline M. 2000. "The Effects of Class Size on Student Achievement: New Evidence from Population Variation." *The Quarterly Journal of Economics* 115 (4): 1239–1285. https://www.jstor.org/stable/2586924.

Kim, Andrew Eungi. 2023. *Scant South Korean Fertility Rate Portends Disaster.* Newspaper, April. https://asiatimes.com/2023/04/scant-south-korean-fertility-rate-portends-disaster/.

King, Elizabeth M, and M Anne Hill. 1997. *Women's Education in Developing Countries: Barriers, Benefits, and Policies.* World Bank Publications.

Korenman, Sanders, and David Neumark. 1997. *Cohort Crowding and Youth Labor Markets: A Cross-National Analysis.*

Kuziemko, Ilyana. 2006. "Using Shocks to School Enrollment to Estimate the Effect of School Size on Student Achievement." *Economics of Education Review* 25, no. 1 (February 1, 2006): 63–75. https://doi.org/10.1016/j.econedurev.2004.10.003.

Lee, Hyeyoung, Jiha Kim, and Sangjin Ma. 2010. "Analysis of the Effects of the Policy of Integrating and Abolishing Small Schools in Rural Areas." *KEDI Working Paper,* 1–364. https://www.kedi.re.kr/khome/main/research/selectPubForm.do?plNum0=8486.

Leithwood, Kenneth, and Doris Jantzi. 2009. "A Review of Empirical Evidence About School Size Effects: A Policy Perspective." *Review of Educational Research* 79, no. 1 (March 1, 2009): 464–490. https://doi.org/10.3102/0034654308326158.

Lewin, Keith M. 2009. "Access to Education in Sub-saharan Africa: Patterns, Problems and Possibilities." *Comparative Education* 45, no. 2 (May): 151–174. https://doi.org/10.1080/03050060902920518.

Mason, Andrew, Ronald Lee, An-Chi Tung, Mun-Sim Lai, and Tim Miller. 2009. "Population Aging and Intergenerational Transfers: Introducing Age Into National Accounts." In

*Developments in the Economics of Aging,* 89–122. University of Chicago Press, March. https://www.nber.org/books-and-chapters/developments-economics-aging/population-aging-and-intergenerational-transfers-introducing-age-national-accounts.

Ministry of Education. 2016. "Strengthening the Development of Schools at the Proper Scale and Encouraging the Use of Closed Schools." Government Website. https://www.moe.go.kr/boardCnts/view.do?boardID=294&boardSeq=63675&lev=0&page=135.

OECD. 2021. *Delivering Quality Education and Health Care to All: Preparing Regions for Demographic Change.* OECD Rural Studies. OECD, March. https://doi.org/10.1787/83025c02-en.

OECD and European Commission. 2021. *Access and Cost of Education and Health Services: Preparing Regions for Demographic Change.* OECD Rural Studies. Paris: OECD, June. https://doi.org/10.1787/4ab69cf3-en.

Prettner, Klaus. 2013. "Population Aging and Endogenous Economic Growth." *Journal of Population Economics* 26, no. 2 (April): 811–834. https://doi.org/10.1007/s00148-012-0441-9.

Sánchez, Jorge Bravo, Mun Sim Lai, Cheryl Sawyer, and Patrick Gerland. 2023. "Population, Education and Sustainable Development." *UN Department of Economic and Social Affairs (DESA) Policy Briefs,* Future of the World, no. 152, 6. https://doi.org/https://doi.org/10.18356/27081990-152.

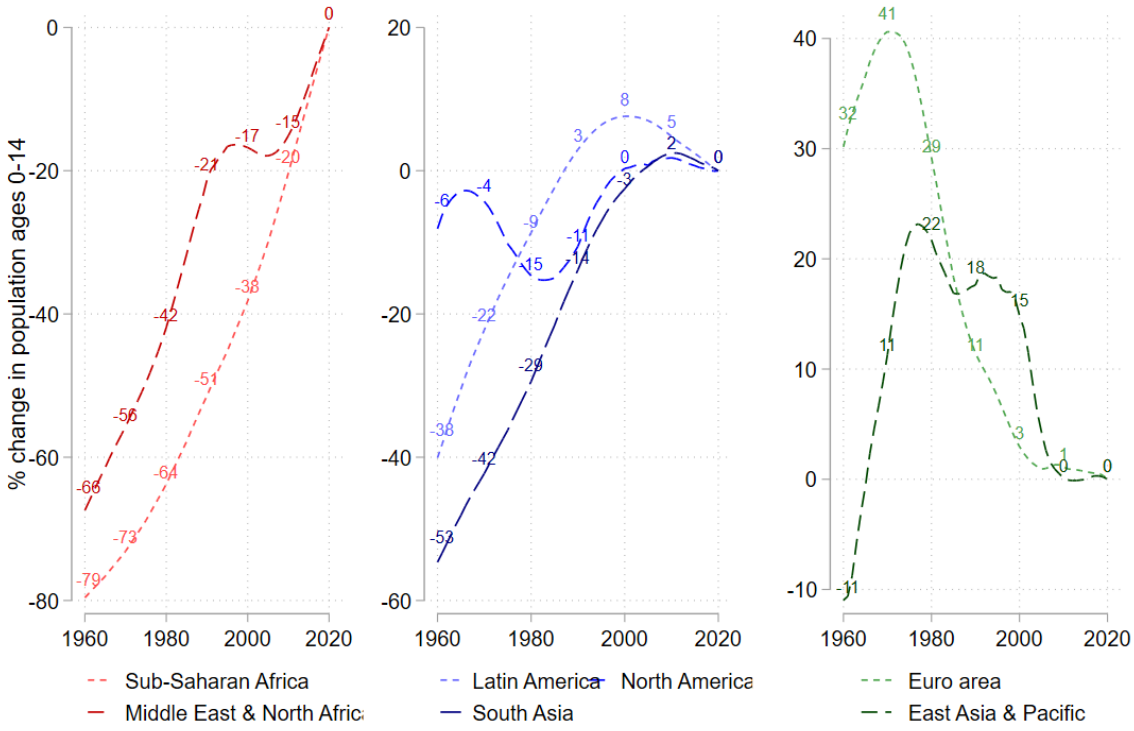
Settersten, Richard A., and Jacqueline L. Angel, eds. 2011. *Handbook of Sociology of Aging.* Handbooks of Sociology and Social Research. New York, NY: Springer New York. https://doi.org/10.1007/978-1-4419-7374-0.

Spaull, Nicholas, and Janeli Kotze. 2015. "Starting Behind and Staying Behind in South Africa." *International Journal of Educational Development* 41 (March): 13–24. https://doi.org/10.1016/j.ijedudev.2015.01.002.

UNESCO Institute for Statistics. 2019. *Education in Africa.* Data Portal. http://uis.unesco.org/en/topic/education-africa.

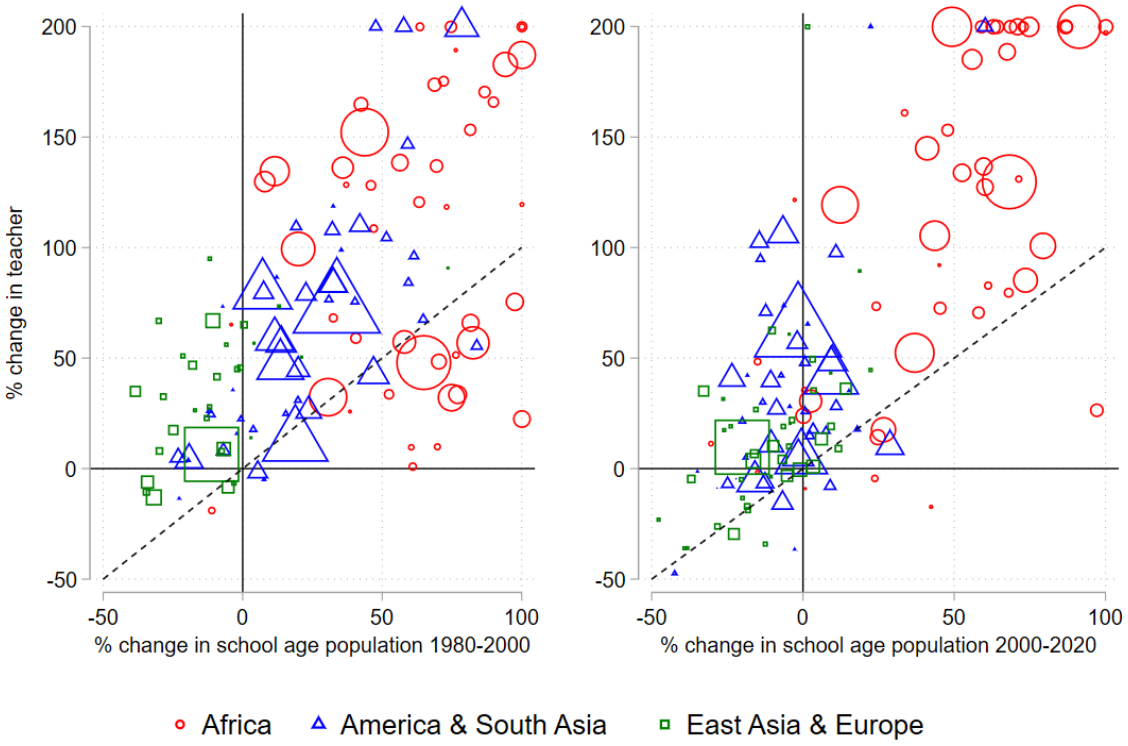
Weizsäcker, Robert K. von. 1996. "Distributive Implications of an Aging Society." *European Economic Review* 40, no. 3 (April): 729–746. https://doi.org/10.1016/0014-2921(95)00085-2.

**Fig. 1.** 1961-2020 School Age Population % Change by Region



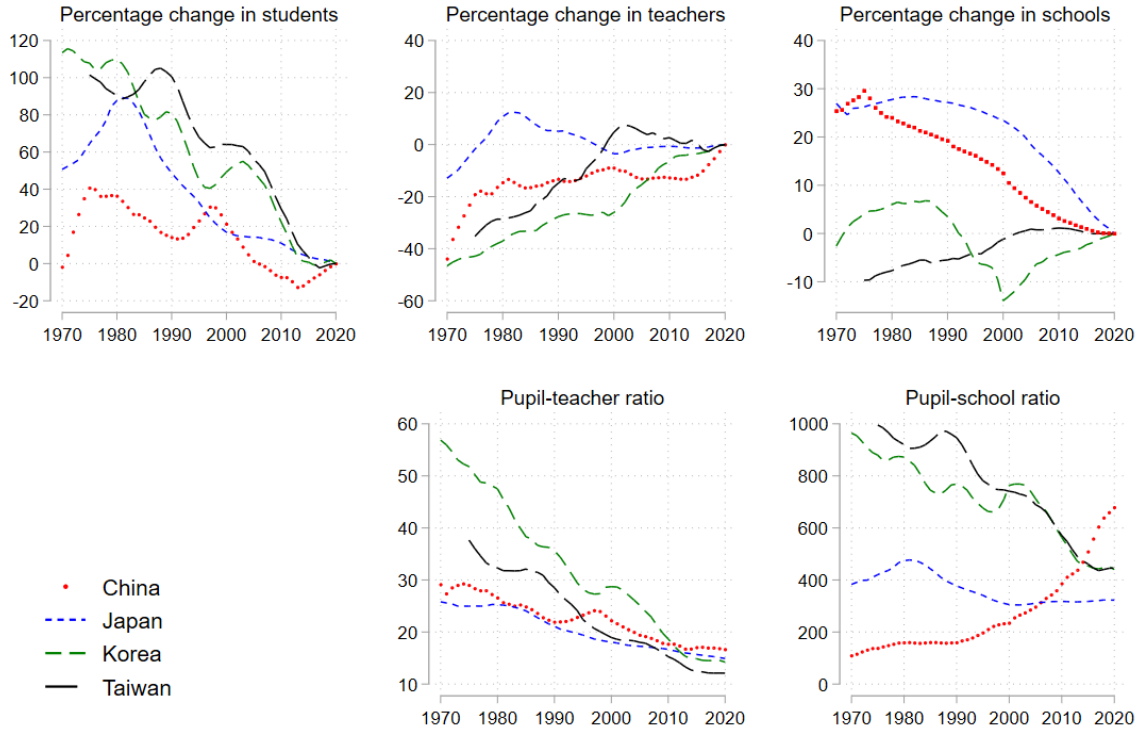

*Note:* The data source is the World Bank World Development Indicators. For simplicity, we treat the child population ages 0 to 14 as the school age population. To facilitate comparisons of trends across countries, for each region, the value shown along the y-axis is the percentage change in school age population as of 2020, which is computed as: $\frac{\text{population}_{\text{year,country}} - \text{Population}_{1981,\text{country}}}{\text{Population}_{1981,\text{country}}} \times 100$.

**Fig. 2.** Percentage Change in the Primary School-Age Population and teacher Counts, 1981-2020



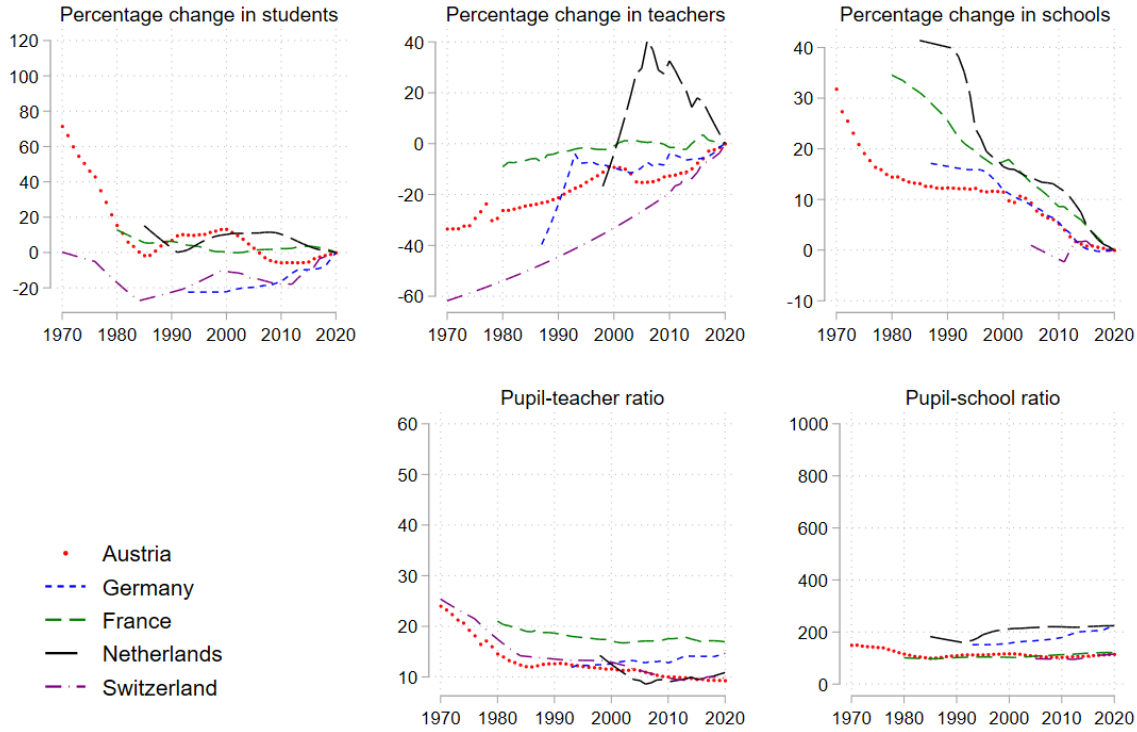

*Note:* The data source is the World Bank World Development Indicators. For simplicity, we treat the child population ages 0 to 14 as the school age population. Countries are included when both primary pupil to teacher ratio and primary school age population data are available for beginning and end years for computing changes. Holding the number of teachers constant and assuming a constant enrollment rate, as school age population increases, the pupil to teacher ratio would increase at the same proportion. Hence, the 45 degree dashed line separates countries that are increasing (below the 45 degree line) and reducing (above the 45 decrease line) the number of teachers in the face of increasing (to the right of the y-axis) or decreasing (to the left of the y-axis) demographics. Specifically, countries in the top-right quadrant and above the 45 degree line experience a reduction in teachers while the school age population expands, and countries in the bottom right quadrant experience a faster rate of increase in teachers than the rate of population expansion. Symmetrically, countries in the bottom-left quadrant and below the 45 degree line experience an increase in the number of teachers while the school age population contracts, and countries in the top-left quadrant experience a reduction in the number of teacher at a faster rate than the rate of population contraction.

**Fig. 3.** Primary Education in East Asia: Demographic Contraction, Schools, and Teachers between 1971 and 2020



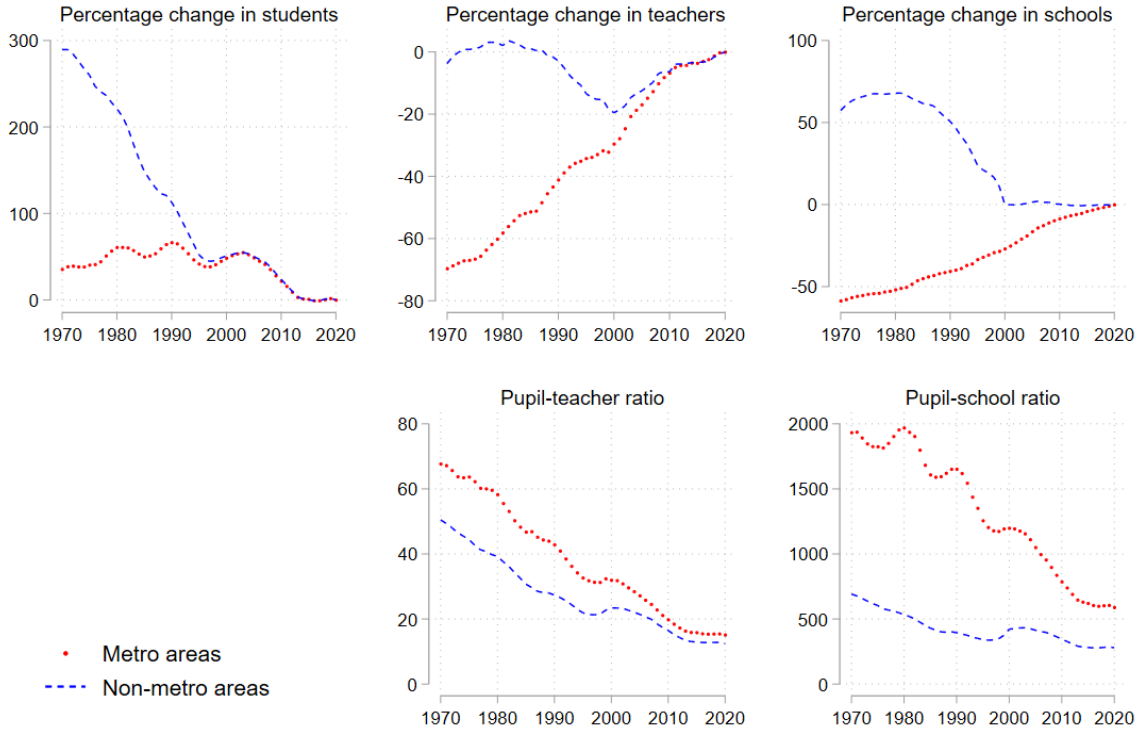

*Note:* The data source is corresponding country's official website. For detail on the data source, see Appendix B. To facilitate comparisons of trends across economies, the value shown along the y-axis for the top three figures of each panel (a) and (b) is the percentage change in each corresponding variable as of 2020, which is computed as: $\frac{\text{Outcome}_{\text{year,country}} - \text{Outcome}_{\text{2020,country}}}{\text{Outcome}_{\text{2020,area}}} \times 100$. Due to the scale difference between China and other economies, we rescaled the percentage change in schools in China by 1/20. A twenty percent change in schools in China represents a one percent change in the figure.

**Fig. 4.** Primary Education in Western Europe: Demographic Contraction, Schools, and Teachers between 1971 and 2020




*Note:* The data source is corresponding country's official website. For detail on the data source, see Appendix B. To facilitate comparisons of trends across economies, the value shown along the y-axis for the top three figures of each panel (a) and (b) is the percentage change in each corresponding variable as of 2020, which is computed as: $\frac{\text{Outcome}_{\text{year,country}} - \text{Outcome}_{\text{2020,country}}}{\text{Outcome}_{\text{2020,area}}} \times 100$.

**Fig. 5.** Primary Education in Korea: Demographic Contraction, Schools, and Teachers in Metropolitan and Non-Metropolitan Areas between 1971 and 2020




*Note:* The data source is Korean Educational Statistics Service (KESS). Both private and public schools are included. The metropolitan areas include the capital area (Seoul, Incheon, Gyeong-gi) and metropolitan cities (Busan, Daegu, Daejeon, Ulsan, Sejong). Non-Metropolitan areas refer to all other areas excluding Metropolitan areas (Gangwon, Chungbuk, Chungnam, Jeonbuk, Jeonnam, Gyeongbuk, Gyeongnam, Jeju). To facilitate comparisons of trends across areas, for each area, the value shown along the y-axis for the top three figures is the percentage change in each corresponding variable as of 2020, which is computed as: $\frac{\text{Outcome}_{\text{year,area}} - \text{Outcome}_{\text{2020,area}}}{\text{Outcome}_{\text{2020,area}}} \times 100$.

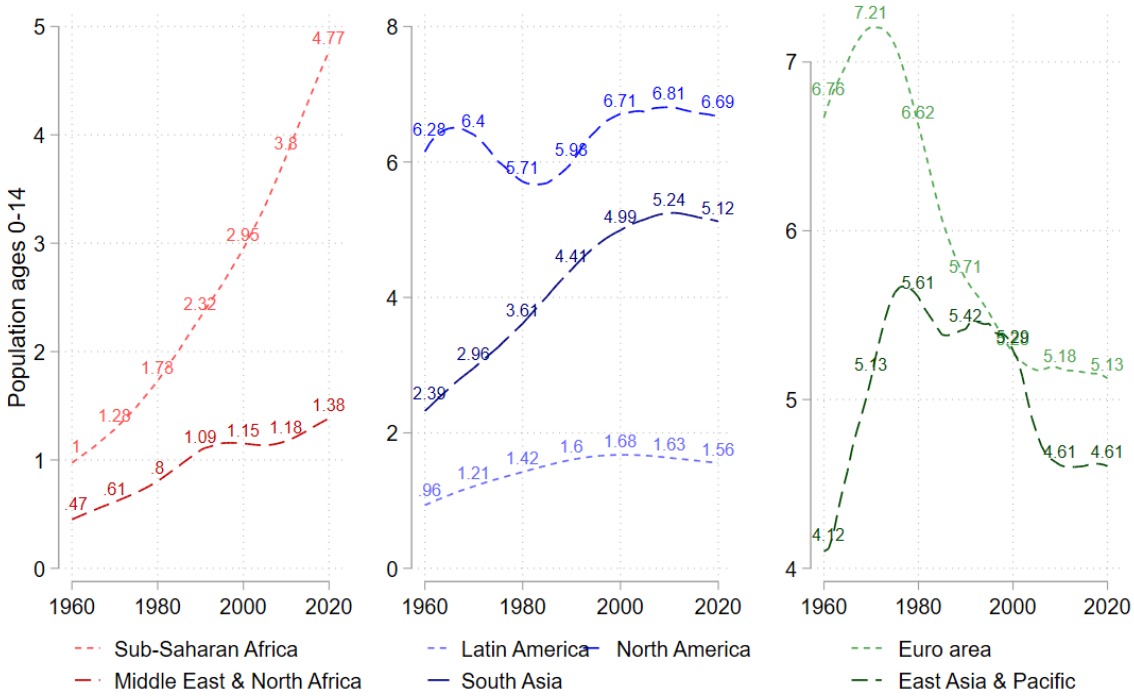
# ONLINE APPENDIX

# From Population Growth to Demographic Scarcity: Emerging Challenges to Global Primary Education Provision in the Twenty-first Century

Emily Hannum, Jeonghyeok Kim, and Fan Wang

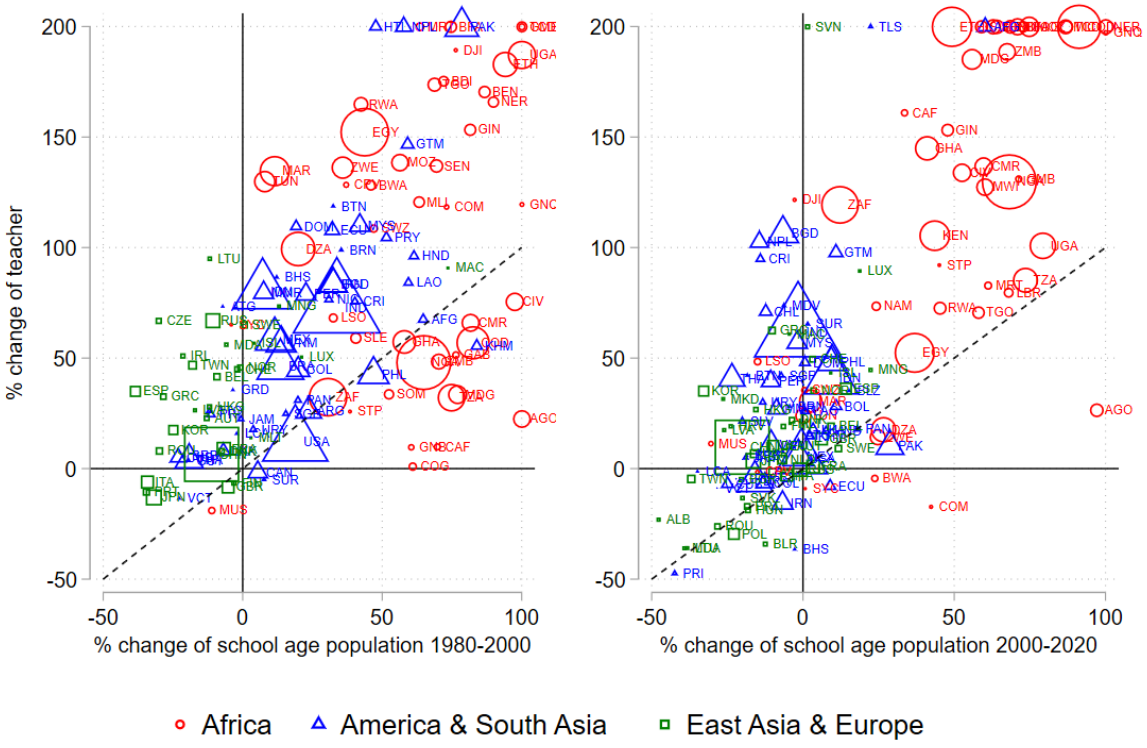
## A Additional Results

**Fig. A.1.** 1961-2020 School-Age Population by Region



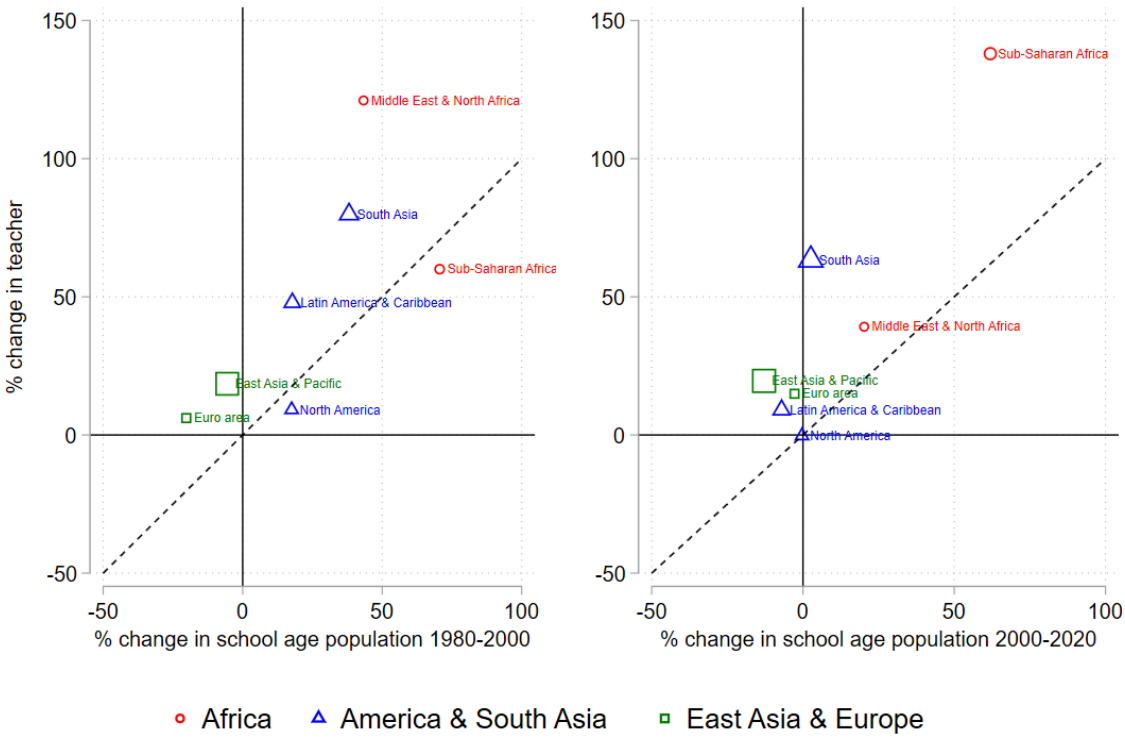

*Note:* The data source is the World Bank World Development Indicators. For simplicity, we treat the child population ages 0 to 14 as the school age population. To facilitate comparisons of trends across countries, for each region, the unit of the value shown along the y-axis varies by country or region. The y-axis unit is 10 million for the Euro Area and North America, but 100 million for all other regions..

**Fig. A.2.** Percentage Change in the Primary School-Age Population and teacher counts With Country Name, 1981-2020



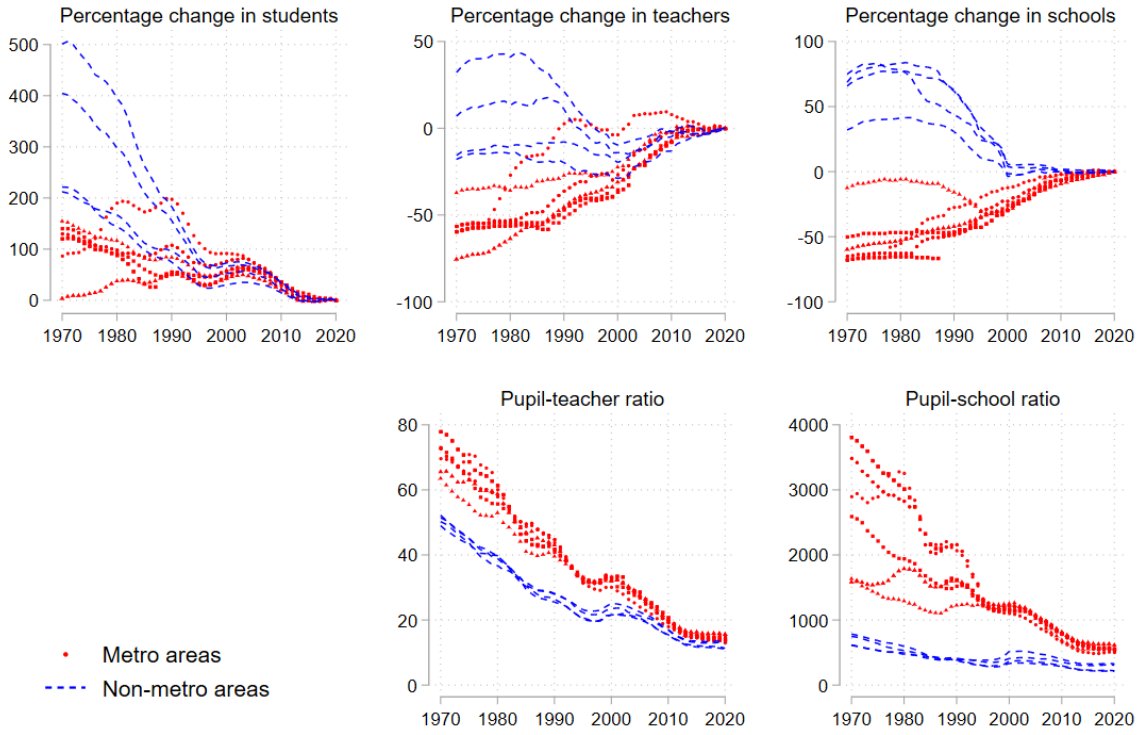

*Note:* The data source is the World Bank World Development Indicators. For simplicity, we treat the child population ages 0 to 14 as the school age population. Countries are included when both primary pupil to teacher ratio and primary school age population data are available for beginning and end years for computing changes. Holding the number of teachers constant and assuming a constant enrollment rate, as school age population increases, the pupil to teacher ratio would increase at the same proportion. Hence, the 45 degree dashed line separates countries that are increasing (below the 45 degree line) and reducing (above the 45 decrease line) the number of teachers in the face of increasing (to the right of the y-axis) or decreasing (to the left of the y-axis) demographics. Specifically, countries in the top-right quadrant and above the 45 degree line experience a reduction in teachers while the school age population expands, and countries in the bottom right quadrant experience a faster rate of increase in teachers than the rate of population expansion. Symmetrically, countries in the bottom-left quadrant and below the 45 degree line experience an increase in the number of teachers while the school age population contracts, and countries in the top-left quadrant experience a reduction in the number of teacher at a faster rate than the rate of population contraction.

**Fig. A.3.** Percentage Change in the Primary School-Age Population and teacher counts by Sub-Region, 1981-2020




*Note:* The data source is the World Bank World Development Indicators. For simplicity, we treat the child population ages 0 to 14 as the school age population. Countries are included when both primary pupil to teacher ratio and primary school age population data are available for beginning and end years for computing changes. Holding the number of teachers constant and assuming a constant enrollment rate, as school age population increases, the pupil to teacher ratio would increase at the same proportion. Hence, the 45 degree dashed line separates countries that are increasing (below the 45 degree line) and reducing (above the 45 decrease line) the number of teachers in the face of increasing (to the right of the y-axis) or decreasing (to the left of the y-axis) demographics. Specifically, countries in the top-right quadrant and above the 45 degree line experience a reduction in teachers while the school age population expands, and countries in the bottom right quadrant experience a faster rate of increase in teachers than the rate of population expansion. Symmetrically, countries in the bottom-left quadrant and below the 45 degree line experience an increase in the number of teachers while the school age population contracts, and countries in the top-left quadrant experience a reduction in the number of teacher at a faster rate than the rate of population contraction.

**Fig. A.4.** Primary Education in Korea: Demographic Contraction, Schools, and Teachers in Metropolitan Cities and Non-Metropolitan Provinces between 1971 and 2020




*Note:* The data source is Korean Educational Statistics Service (KESS). Both private and public schools are included. The metropolitan areas include the capital area (Seoul, Incheon, Gyeong-gi) and metropolitan cities (Busan, Daegu, Daejeon, Ulsan, Sejong). Non-Metropolitan areas include all other areas excluding Metropolitan areas (Gangwon, Chungbuk, Chungnam, Jeonbuk, Jeonnam, Gyeongbuk, Gyeongnam, Jeju). To facilitate comparisons of trends across areas, for each area, the value shown along the y-axis for the top three figures is the percentage change in each corresponding variable as of 2020, which is computed as: $\frac{\text{Outcome}_{\text{year,area}} - \text{Outcome}_{\text{2020,area}}}{\text{Outcome}_{\text{2020,area}}} \times 100$.

Table A.1: East Asia and Western Europe percentages changes in schools, teachers, and youth population between 1961 and 2020.

| | East Asia | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CHN | | | JPN | | | KOR | | | TWN | | |
| | School | Teacher | Youth† | School | Teacher | Youth | School | Teacher | Youth | School | Teacher | Youth |
| Percentage changes in schools, teachers, and youth population | | | | | | | | | | | | |
| 1961-1980 | 26.3% | 104% | 32.7% | -7.1% | 29.7% | -2.3% | | | | | | |
| 1981-2000 | -39.6% | 6.6% | -11.2% | -3.4% | -12.9% | -31.9% | -18.8% | 17.6% | -24.9% | 7.1% | 46.9% | -18.1% |
| 2001-2020 | -71.5% | 9.8% | -20.2% | -19.0% | 3.7% | -16.5% | 16.2% | 35.2% | -32.9% | 1.2% | -4.5% | -37.0% |
| Elasticities of school and teacher count with respect to youth population‡ | | | | | | | | | | | | |
| 1981-2000 | 3.5 | -0.6 | | 0.1 | 0.4 | | 0.8 | -0.7 | | -0.4 | -2.6 | |
| 2001-2020 | 3.5 | -0.5 | | 1.1 | -0.2 | | -0.5 | -1.1 | | -0.0 | 0.1 | |

| | Western Europe | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | AUT | | | DEU | | | FRA | | |
| | School | Teacher | Youth† | School | Teacher | Youth | School | Teacher | Youth |
| Percentage changes in schools, teachers, and youth population | | | | | | | | | |
| 1961-1980 | -21.5% | 28.0% | -1.1% | | | | -25.6% | | 0.6% |
| 1981-2000 | -2.6% | 23.0% | -13.0% | | | | -15.0% | 5.0% | -6.9% |
| 2001-2020 | -10.3% | 10.2% | -4.7% | -10.6% | 26.2% | -9.9% | -15.0% | 5.7% | 3.3% |
| Elasticities of school and teacher count with respect to youth population‡ | | | | | | | | | |
| 1981-2000 | 0.2 | -1.8 | | | | | 2.2 | -0.7 | |
| 2001-2020 | 2.2 | -2.2 | | 1.1 | -2.6 | | -4.5 | 1.7 | |

*Note:* School, teacher, and student count data are obtained from the official statistical records of each country. † Youth are individuals between 0 and 15 years of age. ‡ The elasticity of school (teacher) count with respect to youth population is the ratio of percentage change in school (teacher) count over percentage change in youth population, over the same span of years.

Table A.2: East Asia and Western Europe pupil to teacher and school ratios from 1950 to 2019.

| | Selected years | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1950 | 1960 | 1970 | 1980 | 1990 | 2000 | 2010 | 2019† |
| Panel A. Pupil to teacher-ratio | | | | | | | | |
| Western Europe | | | | | | | | |
| AUT | 25.3 | 24.0 | 24.0 | 14.6 | 12.7 | 11.6 | 10.1 | 9.4 |
| DEU | | | | | | 31.2 | 28.3 | 30.7 |
| FRA | | | | | 24.2 | 22.6 | 22.3 | 21.8 |
| East Asia | | | | | | | | |
| CHN | 32.1 | 34.8 | 29.1 | 26.6 | 21.9 | 22.2 | 17.7 | 16.9 |
| JPN | 36.6 | 34.9 | 25.8 | 25.3 | 21.1 | 18.1 | 16.7 | 15.1 |
| KOR | | | 56.9 | 47.5 | 35.6 | 28.7 | 18.7 | 14.6 |
| TWN | | | | 32.3 | 28.5 | 19.0 | 15.3 | 12.1 |
| Panel B. Pupil to school ratio | | | | | | | | |
| Western Europe | | | | | | | | |
| AUT | 153 | 118 | 150 | 116 | 110 | 117 | 103 | 114 |
| DEU | | | | | | 157 | 179 | 217 |
| FRA | | | | | 106 | 109 | 119 | 130 |
| East Asia | | | | | | | | |
| CHN | 75.4 | 129 | 110 | 160 | 160 | 235 | 386 | 660 |
| JPN | 432 | 469 | 383 | 474 | 378 | 306 | 318 | 323 |
| KOR | | | 964 | 872 | 768 | 763 | 564 | 451 |
| TWN | | | | 920 | 947 | 741 | 571 | 445 |

*Note:* School, teacher, and student count data are obtained from the official statistical records of each country. † 2019 is selected because French data is available up to 2019.

# B Data sources by Country, Teachers, Schools, and Students

Data and statistical programs used by the paper is available at https://fanwangecon.github.io/PrjCompPPTS.

## B.1 Summary

*East Asia*:

- Korea: 1965 to 2021
- Taiwan: 1975 to 2021
- Japan: 1948 to 2022
- China: 1949 to 2021

*Western Europe*:

- Austria: 1923 to 2020
- Germany: 1992 to 2021
- France: 1980 to 2021
- Netherlands: 1990 to 2021
- Switzerland: 1864 to 2020

## B.2 East Asia

### B.2.1 Korea

Sources:

- Korean Educational Statistics Service (link)
  - 1965-2021: yearly province level
  - (elementary) number of schools, teachers, and students

Downloaded:

- Korean elementary school 1965-2021.xlsx

### B.2.2 Japan

Sources:

- Statistics of Japan (link)
  - 1948-2022: yearly
  - (elementary) number of Schools, Students, Teachers

Downloaded:

- japan_school_count_1948_2022.xlsx
- japan_student_count_1948_2022.xlsx
- japan_teacher_count_1948_2022.xlsx

### B.2.3 Taiwan

Sources:

- Ministry of Education (link)
  - 1976-2021: yearly
  - (elementary) Number of Schools, Students, Teachers, enrollment ratio

Downloaded:

- taiwan_students_count_by_levels_1976_2021.csv
- taiwan_teachers_count_by_levels_1976_2021.csv
- taiwan_schools_count_by_levels_1976_2021.csv
- taiwan_gross_enrollment_ratio_by_levels_1976_2021.csv

## B.3 Europe

### B.3.1 Germany

Sources:

- Statistisches Bundesamt (link 1, link 2)
  - 1992-2020: yearly
  - (elementary) Number of Schools, Teachers
  - 1998-2021: yearly
  - (elementary) Number of students

Downloaded:

- germany_schools_classes_bystates_30years.xlsx
  - tab 2.1 number of schools 1992 to 2020
  - tab 7.1 number of teachers 1992 to 2020
- germany_students_total_24years.xlsx

Notes:

- Teachers include full-time employed (Vollzeitbeschäftigte), part-time (Teilzeitbeschäftigte) employed, and hourly employed (Stundenweise beschäftigte) teachers.

### B.3.2 Austria

Sources:

- Statistisches Austria (link 1,link 2, link 3)
  - 1923-2020: yearly
  - (elementary) Number of Schools, Teachers, students

Downloaded:

- germany_schools_classes_bystates_30years.xlsx
- germany_students_total_24years.xlsx

Austrian 100 years student count, class count, and school count.

- austria_school_count_1923_2020.ods
- austria_students_count_1923_2020.ods
- austria_teachers_count_1923_2020.ods

### B.3.3 France

- Repères et références statistiques (link)
  - 1984-2022: year book
  - (elementary) Number of Schools, Teachers, students
- Ministry of National Education and Youth (link 1, link2)
  - (elementary) Number of Schools, Teachers, students

Downloaded:

- 1984-2022 rers.pdf
- france_students_count_1960_2019.xlsx
- france_teachers_rers2021_2008_2020.xlsx
- france_teachers_rers2022_2015_2021.xlsx

Notes:

- Public primary education (elementary + preelementary) data is used. There are multiple reasons for this. First, preelementary education is free since 1883 and the enrollment rate of 3 years old children is 90% and that of 4 years old is virtually 100% in 1970s (Dumas and Lefranc, 2010). Second, data availability is limited if we only focus elementary education, but our analysis shows the qualititively same results.
- Over the period of yearbooks, the coverage regions change. Yearly statistics include overseas departments (Guadeloupe, Guyane, Martinique, and La Réunion) since year 1999 and also include Mayotte since 2011. Also, there are slight data inconsistency across yearbooks when it comes to the number of teachers in year 1992 and 1987. Those changes and inconsistency make jumps between years. To handle this issue, we remove the gap between years by subtracting the gap to previous years.

### B.3.4 Netherlands

Sources:

- Statistis Netherlands(CBS) (link 1,link 2)
  - 1990-2021: yearly
    - (elementary) Number of schools, students
  - 2003-2017: yearly
    - (elementary) Number of teachers

Downloaded:

- netherlands_student_school_count_1990_2021.xlsx
- netherlands_teachers-in-primary-education_2003_2017.xlsx

### B.3.5 Switzerland

Sources:

- HSSO (link)
- Federal Statistical Office (link 1,link 2)
  - 1864-1999: 4-8 years
    - (elementary) Number of students
  - 1864-1961: 4-8 years, 2010-2020: yearly
    - (elementary) Number of teachers
  - 2010-2020: yearly
    - (elementary) Number of schools
      Downloaded:
- swiss_data_students_teachers_schools.xlsx