Misallocation of State Capacity? Evidence from Two Million Primary Schools*

Torsten Figueiredo Walter†

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Abstract

It is well known that average pupil-teacher ratios (PTRs) are higher in poorer countries. This paper shows that PTR variation is also higher, and this helps explain cross-country differences in educational outcomes. I build a new global school-level data set that comprises nearly two million schools and represents the public primary education sector in 91 countries. This allows me to document that variation in school-level PTRs is negatively correlated with per capita income across countries. I further show that in the developing world, (a) PTR variation is a local phenomenon, in the sense that even within second-tier administrative units differences in PTRs between schools are large, (b) PTRs are higher in rural areas, but PTR differences between schools within both urban and rural areas are much larger than differences in average PTRs between urban and rural areas, (c) PTRs are higher in areas where adult literacy is low, and (d) PTRs are higher at schools that also lack other resources, such as classrooms. To assess the relevance of these facts, I build a model of education production. Simulations suggest that test score gains from implementing counterfactual teacher allocations would be substantial in many lower income countries, but only marginal in high-income countries. In contrast, obtaining equivalent gains through reductions in aggregate PTRs, while holding relative PTRs between schools fixed, would require large teacher workforce increases.

Keywords: Development; Education; Inequality; Misallocation; State capacity
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1 Introduction

The formation of human capital through education is key for development.[1] For this reason, a large share of government resources and development aid worldwide is dedicated to education. Nonetheless, education systems in developing countries are characterized by lack of resources, and a large literature documents how this constrains human capital formation.[2]

This paper considers inefficiency of resource allocation within education systems as a complementary explanation of low learning levels in developing countries. In particular, it examines how the allocation of teachers across public primary schools varies between countries and the extent to which this explains differences in educational outcomes. Due to its universality, public primary education provides an ideal setting to study factor allocation within education systems across countries. After all, in nearly every country, primary education is free and compulsory, and public institutions account for the large majority of enrollment.[3] The focus on teachers is founded on their key role for primary education, as highlighted by a long literature emphasizing their importance for pupil achievement, both at school and later in life.[4]

I build a new global school-level data set comprising 1.85 million schools, representing the public primary sector in 91 countries that cover all continents and income levels. I construct this data set from administrative government data on the universe of public primary schools in 77 countries and subsamples in 14 countries. Total enrollment at the contained schools amounts to 314 million pupils, corresponding to one fourth of the global population aged between 5 and 14, who are taught by 13 million teachers.

This data set enables me to uncover large inequalities in access to teachers, as measured by school-level pupil-teacher ratios (PTRs), both across and within countries. In line with existing evidence, I document that aggregate PTRs are higher in poorer countries. Additionally, I reveal that variation in PTRs is negatively correlated with per capita income across countries. For example, in the US, 90% of public primary schools have PTRs between 10 and 25. In Ethiopia, 10% of public primary schools also have PTRs in this range, but at the same time 10% of schools have PTRs above 84.[5]

[1]See the seminal contributions by Becker (1964), Schultz (1960), and Sen (2000) on the importance of human capital formation through education for development.

[2]See Glewwe and Muralidharan (2016) for a recent summary of the literature.

[3]See figures A.1 and A.2 for the number of years of free and compulsory primary education by country. See figure A.3 for the share of public enrollment in primary education across countries by per capita income.

[4]See for example Araujo et al. (2016), Bau & Das (2017), and Chetty et al. (2014b). The importance of teachers is also reflected by the large share of government education expenditure that teacher compensation accounts for. In a typical country almost two thirds of government education expenditure on public primary schools go to teacher compensation. See figure A.5 for details. Moreover, teachers may be the only common input across all income levels - from a rural school under a tree in Mozambique to a modern school in Finland.

[5]Work by international organizations such as the World Bank, UNESCO, and UNICEF has repeatedly drawn attention to imbalances in school staffing across districts and schools within specific African countries (e.g. IIEP Pole de Dakar 2016, Mingat et al. 2003, Mulkeen 2010, UNESCO 2006). In recent years, awareness of this issue has increased and a few studies have examined implications and causes in selected countries (Agarwal et al. 2018 and Pelkonen & Fagernas 2017 in India, Asim et al. 2017 in Malawi).

I further show that in the developing world, (a) PTR variation is a local phenomenon, in the sense that even within second-tier administrative units (e.g. districts or municipalities) differences in PTRs between schools are large, (b) PTRs are higher in rural areas, but PTR differences between schools within both urban and rural areas are much larger than differences in average PTRs between urban and rural areas, (c) PTRs are higher in areas where adult literacy is low, and (d) PTRs are higher at schools that also lack other resources, such as classrooms. The former two facts suggest that in many developing countries a substantially more balanced distribution of PTRs could be achieved by reallocating teachers locally, without transferring teachers between administrative units or rural and urban areas. The latter two facts raise the concern that a more equal distribution of teachers could come at the expense of aggregate learning. If teachers and other inputs into education production are complements, then transferring teachers to schools that do not only lack teachers but also other inputs could lead to a decline in aggregate learning.

To assess the relevance of these facts, I build a stylized model of education production and simulate educational outcomes under counterfactual teacher distributions. In the model, a social planner maximizes aggregate learning of public primary school pupils, as measured by the sum of their scores at national primary school exams, by allocating the existing stock of teachers across public primary schools. Schools produce education using two complementary inputs, teachers and total factor productivity, where the relative importance of teachers (relative to the number of students) is determined by a model parameter.

While the empirical evidence on the importance of school-level PTRs for learning supports the common intuition that a lack of teachers affects pupil achievement negatively, the magnitude of this effect is less clear. Therefore, I conduct all simulations for a set of different values of the aforementioned model parameter. Given the production function and a parameter value, I back out the productivity of each school from the joint variation of exam scores and PTRs across schools, characterizing schools as highly productive if they exhibit a high average score at national primary school exams relative to their PTR.

I simulate two counterfactual teacher distributions. First, I ask how large gains in aggregate learning of public primary school pupils from implementing the optimal allocation of teachers as determined by the model would be. Second, I ask how large gains (or losses) would be if governments were to equalize PTRs using a simple rule-based approach. Specifically, I consider the case where countries set a maximum school-level PTR. In each country, this maximum is chosen such that it is the smallest maximum that can be achieved given the distribution of pupils across schools and the total stock of teachers.

I project that teacher reallocation would only lead to small changes in aggregate learning in developed countries. In many developing countries, however, gains from implementing the optimal allocation given by the model would be significant. Moreover, even simple rule-based teacher reallocation aiming to equalize PTRs across schools would be effective at improving aggregate learning in most of these contexts. For comparison, I show that teacher workforce increases required to obtain equivalent achievement gains through reductions in aggregate PTRs, holding the relative distribution of teachers between schools fixed, would be substantial.

These findings suggest that teacher misallocation by the state is an important obstacle to education in low- and lower-middle-income countries. With 61% of children between the ages of 5 and 14 worldwide living in these countries, the implications for development are far-reaching.[6] Additionally, these results raise the question how important factor misallocation in the public sector is more generally. After all, the state also plays a central role in other important domains, such as health or law enforcement.

This paper makes three contributions. First, by explaining cross-country differences in educational performance as the result of differential input allocation within education systems, it contributes to the education literature, complementing a plethora of micro-economic studies on the causal effects of specific inputs to education on pupil achievement. Second, it contributes to a growing literature on the importance of factor misallocation for aggregate productivity and development. While the existing literature focuses on misallocation in the private sector where factors are allocated across individual decision makers through markets, this paper documents the importance of misallocation in the public sector where factors are allocated by the state.[7] Third, it contributes to the literature on state capacity, demonstrating how comparable administrative government data can be harnessed to study state capacity across a large set countries.

The remainder of this paper is organized as follows. Section 2 describes the data collection process and the resulting data set. Section 3 documents the global inequality in access to public primary school teachers. Section 4 builds a model of education production and Section 5 presents the simulations of counterfactual teacher distributions. Section 6 concludes.

2 Data

2.1 Data collection

Data collection was carried out in three steps as detailed below.

First, I visited the website of the Ministry of Education of every country in the world to look for school census data. In most countries, the Ministry of Education collects this data at least once a year from head teachers and records it in their Education Management Information System (EMIS). It contains basic information on the universe of schools, including enrollment and the number of teachers. If a Ministry of Education did not have a website or I could not find school census data on their website, I visited the website of the Central Statistical Agency. In countries with a decentralized administration of the education system (e.g. Canada), I also visited websites of subnational education authorities. Whenever school census data was publicly available online,

[6]Figure based on 2015 data from the UNESCO Institute for Statistics and World Bank International Comparison Program Database.

[7]Restuccia and Rogerson (2017) provide a recent summary of the literature examining factor misallocation across firms since the seminal papers by Restuccia & Rogerson (2008) and Hsieh & Klenow (2009). Other work has focused on the misallocation of people across sectors and space (Bryan et al. 2014, Gollin et al. 2014, Munshi & Rosenzweig 2016).

I downloaded or scraped it.

In a second step, I sent a data request letter to the Ministry of Education and/or Central Statistical Agency of all remaining countries as long as a point of contact could be found. In some countries with decentralized education systems, data requests were sent to state- or province-level authorities. Overall, I sent out more than 250 data requests in five different languages and followed up extensively on many of these, both in person and through a network of personal contacts, to obtain the requested data.

Third, for all countries where neither of the two previous approaches had been successful, I checked the availability of nationally representative school survey data with information on school-level PTRs.

Overall, I obtained data from 91 countries in 14 different languages and many different formats. At last, I synchronized language and format of the data across countries. Table A.1 gives a detailed overview of the all the data sources and the following subsection provides a description of the resulting data set.

2.2 Data Set

The final data set contains school-level PTR data from 91 different countries across all continents and income levels. Countries can be subdivided into three categories. First, for 77 countries, school census data for the national universe of public primary schools was obtained.[8] Second, for six countries, school census data was only obtained from a subset of states or provinces (covering the universe of public primary schools within those). Third, nationally representative school survey data from eight African countries was added to the data set from PASEC 2014.[9]

The final data set contains information on 1.85 million public primary schools attended by a total of 314 million primary school pupils. Given a total world population between the ages of 5 and 14 of 1.24 billion in 2015, this means it covers 25% of all primary school pupils worldwide. The total number of teachers working at these schools adds up to 13 million. Figure 1 provides an overview of the geographical coverage of the data set.

For each country, the year of the data corresponds to the latest available year at the time of data collection. The majority of the data is from the time period between 2013 and 2017. Only 7 out

[8] It is difficult to assess whether the school census data indeed covers all public primary schools in each of the sample countries and states. However, data on school census return rates from public schools across 49 African countries from the UNESCO Institute for Statistics and World Bank International Comparison Program Database suggests that even in low-income countries data is fairly complete. Return rates are on average 97.3% and only in a handful of countries they are below 90%. See figure A.7. For an additional check, I collect school census time series data from 23 countries. Using data from the last three consecutive years, I check what share of public primary schools reported in year $t-2$ is missing from the data in $t-1$, but reported in t. While it is possible that schools temporarily close and then re-open, such a pattern is highly suggestive of missing schools. Figure A.8 shows that only in South Sudan and Uganda, two countries affected by conflict in recent years, this is common.

[9] PASEC (Programme d'Analyse des Systemes Educatifs de la Conference des ministres de l'Education des Etats et Gouvernements de la Francophonie) regularly conducts representative school surveys in French-speaking Africa. As in the case of the Annual School Censuses, school-level information is reported by school principals.

of 91 country-level data sets are from before 2013, with the earliest data from Botswana in 2009.[10] Table 1 specifies the year of the data for each country and provides basic summary statistics for each country. Further details are documented in table A.1.

While the data is generally restricted to public primary schools, in five countries the data also contains private primary schools as these cannot be differentiated from public schools in the source data. However, in all of these countries the number of private primary schools is negligibly small.[11]

The age at which children start primary education varies little across countries, and is always between 5 and 7.[12] Primary education is most commonly provided through primary schools, but in some countries other school types also provide primary education. For example, in Mongolia primary education is mainly provided at comprehensive schools that run from grade 1 to 12. In order to maintain comparability across schools within each country, the data set is restricted to the types of school that are the primary providers of primary education. Table 1 lists the included types of schools for each country.[13] The number of grades taught in these schools varies substantially across countries and is also indicated in the table. It reaches from 4 to 12 grades. Primary schools with 6 grades are the most common type.[14]

For each school, the data set contains three key pieces of information: number of pupils, number of teachers and school location. PTRs are computed as the ratio of pupil headcount over teacher headcount.[15] While it would be desirable to use full-time equivalents instead of headcounts, such data is rarely available. Hence, for the sake of comparability, headcounts are used whenever possible. However, in ten countries teacher headcounts were not available. In seven of these, teacher full-time equivalents are used instead.[16] In the remaining three countries, the total number of school staff (teachers plus management/administration personnel) is used as the denominator.[17]

I harmonize school location information across countries by defining a region as the highest administrative division of a country (e.g. state or province) or the statistical division that is closest to it (e.g. NUTS-2). A subregion is analogously defined as the second highest administrative

[10] Figure A.9 shows the number of data sets by year.

[11] The respective countries where the data also contains private primary schools are Cape Verde (0.97%), Fiji (0.86%), Saint Vincent and the Grenadines (10.57%), Swaziland (1.55%), and Ukraine (0.58%). The percentage of enrolment in primary education in private institutions in 2015 is given in brackets (source: World Bank International Comparison Program Database). The information for Swaziland is from 2014 as 2015 data was not available.

[12] Figure A.10 shows the distribution of primary school entrance age across all sample countries. The underlying data is from 2015 and was extracted from the website of the UNESCO Institute for Statistics on 13/07/2017.

[13] Apart from the indicated grades, schools may also include pre-primary education.

[14] Figure A.11 shows the distribution of the maximum number of grades taught at included school types across sample countries.

[15] Note that school-level teacher headcounts imply that teachers are counted repeatedly if they work in several schools simultaneously.

[16] The respective countries where teacher full-time equivalents are used to compute school-level PTRs are Brazil, Canada, Ireland, Puerto Rico, Sweden, the UK, and the US.

[17] The respective countries where school staff headcounts were used instead of teacher headcounts are Belgium (Flanders), Fiji, and France.

division of a country (e.g. district) or the statistical division that is closest to it (e.g. NUTS-3). For all but three countries with census data, information on the region in which each school is located was obtained. For 56 countries, subregions are also available. Table A.2 provides further details including the definition of a region and a subregion used throughout this paper for each country. In addition, for 51 countries GPS coordinates of schools were gathered. These were either downloaded or requested from the corresponding Ministry of Education. For 34 countries, GPS coordinates were readily available, for 17 countries school addresses were transformed into GPS coordinates using Google Maps Geocoding API. For few countries, coordinates for all schools could be obtained, but overall the coordinate data is fairly complete. The share of schools for which coordinates are available is on average 94%. Table A.3 provides detailed information on the data source for each country and the completeness of the data.[18]

3 Stylized facts

3.1 PTR variation across countries

It is well-known that national aggregate PTRs are higher in low-income countries. Figure 2(a) illustrates this using UN data. It shows a significant negative correlation between GDP per capita and aggregate PTRs across countries. While aggregate PTRs in primary education are below 30 in all high-income and most upper-middle-income countries, they are above 40 in many low- and lower-middle-income countries. In the poorest parts of the world, they sometimes even reach values above 50.

I replicate this result for the public primary school sector using the data set assembled in this paper.[19] As most primary schools worldwide are public, it is not surprising that Figure 2(b) shows a similarly negative correlation between national aggregate PTR in public primary education and per capita income.[20]

3.2 PTR variation across schools within countries

In this section, I document that there is also a negative correlation between PTR variation and per capita income. Figure 3 shows the PTR distribution across public primary schools in four

[18]In a few countries, a relatively large share of schools has identical coordinates as at least one other public primary school. Table A.3 provides details. In such cases, there may either be several schools within the same building or coordinates do not reflect the actual location of the school, but rather the centroid of the administrative division within which a school is located. Without additional information, it is not possible to differentiate between these two cases. Therefore, I replicate all subsequent results using GPS coordinates excluding schools that share identical coordinates with other schools and show that they are robust. The results from this exercise are available upon request.

[19]For a given country, the national aggregate PTR is computed as the total number of pupils over the total number of teachers in all public primary schools contained in the data. The total number of teachers is computed as the sum of teacher headcounts over all schools. To the extent that teachers work in several schools simultaneously and are counted repeatedly, computed national aggregate PTRs will underestimate actual national aggregate PTRs.

[20]Figure **??** plots the share of primary school pupils enrolled in public institutions across countries by per capita income.

different countries - a low-income country (Mozambique), a lower-middle-income country (India), an upper-middle income country (Peru) and a high-income country (US).[21] A comparison of these four distributions yields three observations. First, in line with the results presented in the previous section, the average PTR in the low-income country Mozambique is substantially higher than in the other countries. While the mean PTR is 59.8 in Mozambique, it is only 24.9 in India, 14.2 in Peru and 16.5 in the US. Second, cross-school PTR variation is large in the lower income countries, but small in the higher income countries. The cross-school PTR standard deviation amounts to 27.4 and 18.2, respectively, in Mozambique and India, but it measures only 6.8 and 4.1, respectively, in Peru and the US. Third, the poorer a country, the longer is the right tail of schools with high PTRs.

These observations hold more generally. Figure 4(a) shows the cross-school PTR standard deviation within each country against per capita income. Evidently, cross-school PTR variation in the public primary education sector is negatively correlated with per capita income across countries. In high- and upper-middle income countries the standard deviation ranges between 1 and 10. In the majority of low- and lower-middle-income countries, it is larger than 15.

Figure 4(b) confirms that there is a long right tail of schools with high PTRs in lower income countries which does not exist in higher income countries. The length of the tail of the distribution is measured by the difference between the 90th and the 50th percentile of the cross-school PTR distribution. The long right tail in many developing countries implies that a lot of children attend schools with few teachers - even in countries where aggregate PTRs in the public primary education sector are not extremely high. In India, for example, 35% of public primary education pupils attend schools with a PTR above 40 despite a national PTR of 26. Across all sample countries with census data, 9% of children are enrolled in schools with PTRs above 80 while this could be entirely avoided in all countries but Mali if teachers were more evenly distributed across public primary schools within countries.

It is important to note that the negative association between PTR dispersion and per capita income is not simply a consequence of high aggregate PTRs in low-income countries. While it can be shown through simulations that the indivisibility of teachers causes PTR variation to increase in aggregate PTR even if the objective is to equalize PTRs across schools, this effect is quantitatively small relative to the PTR variation observed in low- and middle-income countries (see appendix section A.1 for details). Hence, the overall lack of teachers per se does not inhibit a much more equal distribution of teachers across schools in developing countries.

3.3 The spatial distribution of PTRs within countries

This section examines the spatial disparities in PTRs within countries. First, I show that PTR variation is a local phenomenon in many developing countries, in the sense that even across schools within the same subregion PTRs differ substantially. Second, I document that PTRs are higher in rural areas of developing countries, but PTR differences between schools within both urban and

[21] The data for each country are trimmed at bottom and the top. The 1st and the 99th percentile of the PTR distribution are excluded.

rural areas are much larger than differences in average PTRs between urban and rural areas.

Figure 5 shows the spatial variation of PTRs across public primary schools in Zambia. The map indicates areas around schools with high PTRs in increasingly dark shades of red and areas around schools with low PTRs in increasingly dark shades of green. It stands out that the heat map is relatively spotty, i.e. there is a lot of variation even within districts. A similar pattern can be observed in other developing countries.[22] A PTR variance decomposition shows that both between- and within-region and -subregion variations are larger in lower income countries. But while within- and between-variation are of similar magnitude in higher income countries, in lower income countries the within-variation is substantially larger than the between-variation. As shown in Figures 6(a) and 6(b), in many developing countries the within-region and the within-subregion standard deviation in PTRs exceeds 10 while the corresponding between-variation is considerably smaller.

To assess differences in PTRs between urban and rural areas, I construct three distinct measures of school remoteness for all schools for which coordinates were obtained:

1. Population density within a circle of 3km radius around the school based on Global Human Settlement (GHS) data[23]
2. Nighttime luminosity within a circle of 3km radius around the school based on 2015 data from the Earth Observation Group, NOAA National Geophysical Data Center[24]
3. Travel time to closest city based on the accessibility to cities dataset from the Malaria Atlas Project at Oxford University (Weiss et al. 2018)

Then I run a separate regression of the following form for each country with available school coordinates:

$$PTR_s = \alpha + \beta remote_s + \epsilon_s$$

where $remote_s$ stands for the remoteness of school s as measured by one of the three measures listed above.

Figure 7 plots the estimated regression coefficients and the adjusted R^2 for each country against per capita income. I find that remoteness is weakly positively correlated with PTRs in most low- and lower-middle-income countries, but it can only explain a very small share of the overall variation in PTRs as indicated by the low R^2 in these countries. So, while PTRs are higher in rural areas of developing countries, PTR differences between schools within both urban and rural areas are much larger than differences in average PTRs between urban and rural areas.[25]

[22] PTR heat maps from other countries where school coordinates were obtained are available upon request.

[23] Subsequent results are robust to setting the radius of the circle around the school to 1km or 5km instead.

[24] Subsequent results are robust to setting the radius of the circle around the school to 1km or 5km instead.

[25] A corresponding analysis using rural/urban indicators as provided in the school census data in a subset of 30 countries also leads to the same conclusion. See figure A.18. Since the underlying rural/urban indicators are not comparable across countries, results should be interpreted with care.

One implication of the facts documented in this section is that in many developing countries a substantially more balanced distribution of PTRs could be achieved by reallocating teachers locally, without transferring teachers between administrative units or rural and urban areas.

3.4 PTRs and other inputs to education

In this section, I assess the correlation between PTRs and other inputs to education in developing countries. I show that schools with less teachers also tend to have less classrooms and toilets (relative to pupils). Moreover, the parents of pupils at these schools tend to be less educated.

To examine the correlation between the supply of teachers and other school inputs, I exploit information on classrooms and toilets provided in various school surveys and annual school censuses as shown in Table A.4. Then I run a separate regression of the following form for each country and input factor:

$$PTR_s = \alpha + \beta PIR_s + \epsilon_s$$

where PIR_s stands for the pupil-input ratio at school s.

Figure 8 shows the resulting regression coefficients across countries. In all examined countries, PTRs are positively correlated with pupil-classroom and pupil-toilet ratios, although to different extents. Thus, schools with less teachers tend to be less well- equipped more generally.

To understand the relationship between school-level PTRs and parental education, I carry out two complementary analyses. First, I correlate PTRs with the literacy of pupils' mothers as given in various school surveys, as given in Table A.6. Second, I spatially match schools to DHS (latest survey)[26] and Afrobarometer (Round 6) clusters and correlate average PTRs with adult literacy rates at the cluster level. In all countries where school coordinates as well as DHS and/or Afrobarometer data are available, I assign all schools within a 10km radius to a given cluster.

The results displayed in Figures 9 and 10 show that in most developing countries, pupils' mothers' literacy and local adult literacy are negatively correlated with school-level PTRs. In other words, the unequal distribution of teachers across schools tends to aggravate existing educational inequalities even further.

The findings from this section also raise the question to what extent a more equal distribution of teachers could come at the expense of aggregate learning. If teachers, classrooms and other school infrastructure as well as parental education are complementary inputs into the production of education, then transferring teachers to schools that do not only lack teachers but also these other inputs could lead to a decline in aggregate learning.

[26] Table A.5 provides an overview of the utilized DHS waves.

4 Model

The previous section has highlighted that teachers are distributed very unequally across public primary schools in many developing countries. However, local teacher reallocation could go a long way towards a more balanced distribution since a large share of cross-school PTR variation is within second-tier administrative units. The fact that the availability of other inputs to education, such as classroom and parental education, is positively correlated with the presence of teachers, though, raises the question whether teacher reallocation could lead to losses in aggregate learning.

In this section, I build a simple model of education production to formalize this concern. In the following section, I then use this model to simulate the effects of alternative teacher allocations on pupil achievement.

The setup is as follows. A social planner allocates homogeneous teachers across public primary schools subject to a budget constraint. The objective of the social planner is to maximize total learning, as measured the sum of pupil test scores in the country:

$$\begin{aligned}
\max_{T_s} \quad & \sum_s \frac{P_s}{\sum_j P_j} H_s(T_s, .) \\
\text{s.t.} \quad & H_s = A_s \left(P_s / T_s\right)^{\beta} \\
& -1 < \beta < 0 \\
& \sum_s w(1+\tau_s) T_s \leq B
\end{aligned}$$

where P_s indicates the number of pupils in school s and T_s the number of teachers. H_s is the average test score which is weighted by the enrollment at the school P_s relative to the enrollment in the entire public primary school sector $\sum_j P_j$. The education production function features two complementary inputs: teachers T_s (relative to the number of pupils) and a school-specific productivity term A_s which does not only capture productivity in the conventional sense, but also absorbs school-specific demand factors, such as household preferences, returns to education and opportunity costs. The parameter restriction on β ensures diminishing marginal returns to teachers. The cost of having a teacher at school s is set to $w(1+\tau_s)$ and the budget constraint says that the total cost for teachers cannot exceed the budget B. τ_s captures differences in teacher allocation costs across schools.

The model makes several stark assumptions. First, teachers are assumed to be homogeneous. Treating teachers as perfect substitutes to each other is supported by the fact that there is typically very limited subject specialization among primary school teachers. Teachers frequently teach all subjects to a given class. However, quality differences between teachers certainly exist. Empirically these are difficult to measure, though. Usually, they are quantified using teacher value-added models (Chetty et al. 2014a, Rothstein 2016), but these require detailed panel data on pupils and teachers which is not available in many of the countries I study. Hence, I restrain from incorporating teacher quality differences in my analysis.

Second, the model does not consider out-of-school children. This is motivated by the fact that even in low-income countries "most children today enroll in primary school" (World Bank 2018). Using data from Afrobarometer 2016 on school enrollment across 36 African countries, I confirm that among the youngest cohort participating in the survey (born in 1997) less than 5% never enrolled in school. Moreover, the share of adults that has never enrolled in school has declined steadily since 1950 (see figure A.6 for details). Therefore, today the share of children that never enroll is likely to be even smaller.

5 Simulations

5.1 Counterfactuals

To quantify the potential gains and losses from teacher reallocation, I simulate the effects of two distinct counterfactuals. First, I ask how large gains from implementing the nationwide optimal allocation of teachers as determined by the model would be. Second, I ask how large gains (or losses) in learning of public primary school pupils would be if countries distributed teachers according to a rule that aims to equalize PTRs across schools subject to indivisibility of teachers. Specifically, I assume countries set a maximum PTR that cannot be exceeded at any school, where this maximum is chosen such that it is the smallest maximum that can be achieved given the distribution of pupils across schools and the total stock of teachers in the country.

5.2 Data

For the simulation of the above counterfactuals, I use school-level average scores at national primary school examinations from ten countries. These ten countries are selected based on data availability and stretch across four continents, from some of the poorest to some of the richest countries in the world. Details on the examinations are available in Table A.8.

Within each country, I normalize scores such that they range between 0 and 100 by dividing original scores by the maximum achievable score. Figure 12 shows the distribution of normalized scores in each of the ten countries.[27]

5.3 Calibration

The key parameter in the presented model is β, the effect of school-level PTR on test scores. School-level PTRs can affect learning through various channels. Most importantly, larger school-level PTRs are associated with larger class sizes, as shown for six developing countries with available class size data in Figure 11. Other potential channels include the increased use of multigrade

[27] In countries where the lowest possible scores is above zero, I first subtract this minimum score. In countries where exam scores are fitted to a given distribution, I set the minimum score to three standard deviations below the mean and the maximum score to three standard deviations above the mean.

teaching and shortened instruction time due to multishift teaching in response to the relative lack of teachers.

The empirical evidence on these channels points to a negative effect of lack of teachers on pupil achievement. The seminal papers on class size effects by Krueger (1999) and Angrist and Lavy (1999) find that class size reductions in primary school lead to small, but statistically significant increases in test scores in the short-run. Krueger (1999) estimates gains in standardized test scores from marginal class size reductions of the magnitude of 0.048, Angrist and Lavy (1999) find effect sizes between 0.017 and 0.071. Since then, many studies have applied the regression discontinuity design pioneered by Angrist and Lavy (1999) in comparable settings all over the world. Many of these studies have also found small, but statistically significant effects[28] whereas a few have failed to identify statistically significant effects.[29]

All of these studies identify class size effects from small changes in class size and none of them consider settings with class sizes above 40. However, as Bandiera et al. (2010) show in the context of course size at university, class-size effects are likely to be non-linear and could be significantly larger as classes become very large. Therefore, the above estimates may underestimate average class-size effects in low-income countries. On the other hand, for class size reductions to be effective the presence of complementary inputs is important, as shown by Duflo et al. (2015). In an experimental study in Kenya, they find that the effectiveness of class size reductions crucially depends on teachers incentives. Given weak teacher incentives in many developing countries, the estimates from developed countries could thus also overestimate effects in developing countries.

While the evidence on class-size effects on test scores in the short-run is not definite, the available evidence on the long-run effects finds unambiguously large positive effects from class-size reductions in kindergarten (Chetty et al. 2011) and primary school (Fredriksson et al. 2013). For example, Fredriksson et al. (2013) find that reducing class size in primary school by one pupil leads to an increase in educational attainment by 0.05 years at age 27, suggesting that even small short-run test score gains from class size reductions in primary school can have important long-run consequences.

Empirical evidence on the second channel, multi-grade teaching, is limited but the available research finds that it is harmful to student performance (Checchi & De Paola 2017, Gerhardts et al. 2016, Jacob et al. 2008, Sims 2008). Checchi and De Paolo (2017), for example, estimate that learning in a multi-grade class until the 5th year of primary school in Italy leads to a 0.5 standard deviation decrease in numeracy test scores compared to learning in a single-grade class. The negative effects of multi-grade are likely to be even larger in low-income countries where unlike in developed countries, multi-grade teaching is not necessarily restricted to adjacent grades, but can also involve mixing pupils from several non-adjacent grades.

The literature on the third channel, instruction time, finds largely positive effects on pupil

[28] See Bressoux et al. (2009) for results from France, Fredriksson et al. (2013) for results from Sweden, Hojo (2013) for results from Japan, Nandrup (2016) for results from Denmark, and Urquiola (2006) for results from Bolivia.

[29] See Hoxby (2000), Levin (2001), and Angrist et al. (2017).

performance (e.g. Lavy 2015). However, it also points out that magnitudes depend on the quality of instruction and children's alternative time use (e.g. Rivkin and Schiman 2015) and therefore estimates must be expected to vary across settings.[30]

It is not clear how to aggregate the effects of class size, multi-grade teaching and instruction time to arrive at an estimate of the effect of school-level PTR on test scores. However, there is one paper that directly investigates the effect of school-level PTRs on pupil performance. Muralidharan & Sundararaman (2013) conduct a randomized control trial across public primary schools in rural Andhra Pradesh, India. Treatment schools obtain an extra contract teacher, inducing an average PTR reduction by 10.814. The authors show that a one unit reduction in PTR leads to an increase in standardized test scores by 0.0144 standard deviations after two years, thus confirming that a lack of teachers has negative implications for pupil learning.[31,32] It is also noteworthy that Muralidharan & Sundararaman fail to find evidence of heterogeneous effects with respect to student and household characteristics, consistent with the model assumption that PTR effects do not depend on individual characteristics.

In summary, the available evidence is line with the common intuition that a lack of teachers affects pupil achievement negatively. The magnitude of this effect, however, is uncertain and likely context-dependent. Therefore, I vary the model parameter β in the following simulations and assess the sensitivity of my results to the magnitude of β.

For all simulations, I initially assume that teacher allocation costs are equal across schools within a country: $\tau_s = 0$ for all schools s. Afterwards, I use information on teacher salary differences between schools from two countries to assess the budgetary implications of the proposed counterfactual teacher distributions (see Section 5.5). The model underlying the following simulations can be summarized as follows:

$$
\begin{aligned}
\max_{T_s} \quad & \sum_s \frac{P_s}{\sum_j P_j} H_s(T_s) \\
\text{s.t.} \quad & H_s = A_s \left(P_s / T_s\right)^{\beta} \\
& -1 < \beta < 0 \\
& \sum_s T_s = \bar{T}
\end{aligned}
$$

where $\bar{T}$ stands for the total number of teachers.

Since for each school, the average test score H_s and the pupil-teacher ratio PTR_s are observed,

[30]See the literature section in Barrios & Bovini (2017) for a short summary of the literature.

[31]The authors do not directly report this estimates. Instead they report the average reduction in PTR induced by the treatment and the average effect of the treatment on test scores. Dividing the latter (0.156 after two years) by the former (10.814 after two years), I derive the reported estimates.

[32]Chin (2005) also finds positive effects from adding teachers to small schools in India on school completion rates, but does not report the induced reductions in PTRs.

I can recover A_s for all schools s from the data as:

$$A_s = \frac{H_s}{PTR_s^{\beta}}$$

Intuitively, this formulation characterizes schools with high PTRs and high exam scores as productive and schools with low PTRs and low exam scores as unproductive.

5.4 Results

5.4.1 Counterfactual 1: Nationwide optimal allocation

In this subsection, I ask how large gains from allocating teachers optimally would be.[33] With $-1 < \beta < 0$, the below first-order condition is necessary and sufficient for optimality:

$$A_k \left(\frac{P_k}{T_k}\right)^{1+\beta} = A_m \left(\frac{P_m}{T_m}\right)^{1+\beta} \quad \forall k, m$$

Since $A_s = H_s / PTR_s^{\beta}$, these marginal products can be rewritten and computed as

$$A_k \left(\frac{P_k}{T_k}\right)^{1+\beta} = H_k PTR_k$$

Figure 13 shows the distribution of marginal products across public primary schools in the ten examined countries. It is evident that marginal products vary substantially in poorer countries, but are relatively similar between schools in high-income countries.

The gains from the optimal allocation are displayed in Figure 14. Figure 14(a) shows the percentage gain in the average exam score that could be achieved by implementing the optimal allocation. The model projects only small gains in Brazil, Sweden, the UK and the US, independent from the value of β. In all other countries, gains are projected to exceed 3% for large β, with especially large gains in India (7.6%) and Mexico (9.7%). For smaller values of β projected gains are correspondingly smaller.

For comparison, I ask by how much the teacher workforce would have to be increased to achieve equivalent gains if relative PTRs between schools were fixed. Figure 14(b) shows how large these increases would have to be in the different countries. Even for small values of β these would amount to close to 10% and more in all developing countries but Brazil. Thus, it appears that teacher reallocation could be a cost-effective alternative to the hiring of additional teachers in these contexts (see Section 5.5 for a discussion of reallocation costs).

Interestingly, the projected gains come at the cost of increased PTR inequality in some countries, but not in others. As Figure 15 shows the optimal PTR distributions in Tanzania, Zambia

[33] For computational reasons, I allow for divisibility of teachers. Solving this high-dimensional optimization problem is computationally much more demanding when adding an integer constraint for each school.

and the Dominican Republic are less dispersed than the actual ones. In India and Mexico, on the other hand, the optimal distributions are more dispersed. Thus, gains in aggregate learning would come at the expense of rising inequality in these countries.

5.4.2 *Counterfactual 2: Nationwide rule-based PTR equalization*

In many countries, the allocation of teachers to schools is based on rules that aim to equalize school-level PTRs or class sizes. These rules can take the form of internal guidelines of Ministries of Education or of explicit laws. Typically they set a maximum school-level PTR that cannot be exceeded at any school (e.g. Right to Education Act in India) or a maximum class size (e.g. Maimonides' rule in Israel).[34]

In this subsection, I simulate the distribution of teachers under the smallest achievable maximum PTR rule in each country. First, I compute the smallest threshold x that can be satisfied given the current stock of teachers and the distribution of pupils across schools such that the PTR does not exceed x at any school.[35] Then, I distribute teachers based on this allocation rule, as shown in Figure 16. Finally, I project the aggregate learning gains from this counterfactual distribution using the education production function.

I find that according to the model, the proposed rule-based reallocation would not lead to losses in aggregate learning in most countries. As Figure 17(a) illustrates, the model projects positive gains for all countries but Brazil and Sweden where reallocation would imply small losses. In the high-income countries of the US and the UK, gains in average exam scores are projected to be minimal, but in the developing countries apart from Brazil they range between 0.5% and 5.1%, depending on the country and the magnitude of β. With equivalent teacher workforce increases between 4% and 18% (see Figure 17(b)), these effects are not negligible, thus suggesting that a more equal distribution of teachers across schools could not only improve equality of opportunity among children, but also contribute to aggregate learning in developing countries.

5.5 Budgetary implications

How would the simulated teacher reallocation scenarios affect budgets for teacher compensation? Many countries pay hardship allowances to teachers working in remote areas or under otherwise difficult conditions (Pugatch & Schroeder 2014).[36] If the simulated optimal allocation or the smallest achievable maximum PTR rule implied a large shift of teachers from schools where teachers

[34] Other countries with maximum PTR or maximum class size rules are for example Belgium, Germany, Italy, the UK and Zambia.

[35] To compute the smallest achievable threshold x, I use a simple algorithm that starts by simulating the implementation of a maximum PTR of 2. First, it calculates the number of teachers required for this at each school given enrollment. Second, it checks whether the total number of teachers required in all schools is weakly smaller than the total stock of available teachers. If this is not the case, the algorithm continues to the next step and simulates the implementation of a maximum PTR of 3. From then on, the algorithm continues simulating the implementation of increasingly higher maximum PTRs until the stock of available teachers is sufficient to implement the given maximum PTR.

[36] See also World Bank SABER.

are not paid hardship allowances to schools where they are, then they would lead to significant increases in total teacher compensation costs. To understand the budgetary implications of the simulated counterfactuals, I collect data on hardship allowance schemes in two countries, Tanzania and Zambia, and simulate the budgetary effects of the alternative allocations. Tanzania does not have a hardship allowance scheme and therefore, the teacher compensation budget would not be affected by the counterfactual teacher distributions there. Zambia, on the other hand, has a hardship allowance scheme, but I compute that the budget necessary to pay all teachers after reallocation would only be marginally larger than the current budget - by 0.7% in the case of the optimal allocation and by 0.1% in the case of the rule-based PTR equalization.[37] Hence, the simulated counterfactual teacher allocations would essentially be budget-neutral in the two examined countries.

While it is unclear what the fixed costs of teacher reallocation would be, the simulation results underline that improving the efficiency of teacher allocation may be significantly more cost-effective than hiring additional teachers.

6 Conclusion

I study the importance of factor misallocation by the state for development. Focusing on the allocation of teachers across public primary schools, I provide evidence that learning gains from implementing alternative teacher allocations could be substantial in many lower income countries. I project that average national primary school exam scores could be improved by up to 10% by reallocating the existing stock of teachers optimally across schools within these countries. Even simple rule-based teacher reallocation aiming to equalize PTRs across schools would be effective at improving aggregate learning in most of these contexts. At the same time, it would decrease inequality of opportunity, thereby limiting aggregate productivity losses due to ensuing misallocation of talent.

For comparison, I show that teacher workforce increases required to obtain equivalent pupil achievement gains through reductions in aggregate PTRs, holding the relative distribution of teachers between schools fixed, would be substantial. Permanent salary costs of reallocation due to hardship allowance payments at unattractive schools, on the contrary, are projected to be minimal. Hence, improving the efficiency of teacher allocation in lower income countries appears to be more cost-effective at improving educational outcomes than augmenting the stock of teachers.

In conclusion, this paper suggests that teacher misallocation is an important obstacle to learning in developing countries. Thereby, it complements a large set of micro-level studies on the importance of selection, training and incentives for teachers, highlighting that inefficient teacher

[37] I use government payroll data for the universe of government employees in the education sector to determine at which schools hardship allowances are paid and how much they are. I manage to match information from the payroll system to 92% of public primary schools with exam score data and use only this subset of schools for the simulation of the budget effects.

allocation is an additional barrier to educational performance.[38]

With 61% of children between the ages of 5 and 14 worldwide living in low- and lower-middle-income countries, the implications for development are far-reaching. Naturally, questions about the reasons of the suboptimal allocation of teachers in these countries arise. My own work in Zambia (Figueiredo Walter 2018) along with other available evidence points to a combination of political patronage and lack of managerial capacity, and governments of many of the concerned countries have raised these issues themselves.[39] For example, a government report from Cameroon finds that "imprecise management, in particular with regards to the allocation of teachers across schools, results in both an efficiency and an equity problem" (Ministere de l'Economie, de la Planification, et de l'Amenagement du Territoire, Republique du Cameroun 2013). A detailed exploration of the underlying causes and potential remedies is therefore an important topic for future research.

The implications of this paper also go beyond the issue of teacher allocation. It illustrates how administrative government data from a large set of countries can be harnessed to study the efficiency of public resource allocation across all stages of development. In doing so, it calls for further research on the importance of factor misallocation in the public sector. After all, the state also plays a central role in other important domains, such as health or law enforcement, and the revealed patterns are unlikely to be constrained to the education sector.

[38]See for example Muralidharan & Sundararaman (2011) and De Ree et al. (2018) on financial incentives for teachers, Duflo et al. (2012) and Muralidharan et al. (2017) on the monitoring of teachers, Bold et al. (2017) on teacher training, and Rockoff et al. (2011) on teacher selection. Work by Dal Bo et al. (2013) and Ashraf et al. (2018) on the selection of state-employees is also related.

[39]See Asim et al. (2017) for evidence from Malawi, Cummings & Tahirou (2016) for evidence from Niger, Diompy (2014) for evidence from Senegal, and Ramachandran et al. (2018) for evidence from India.

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Figures

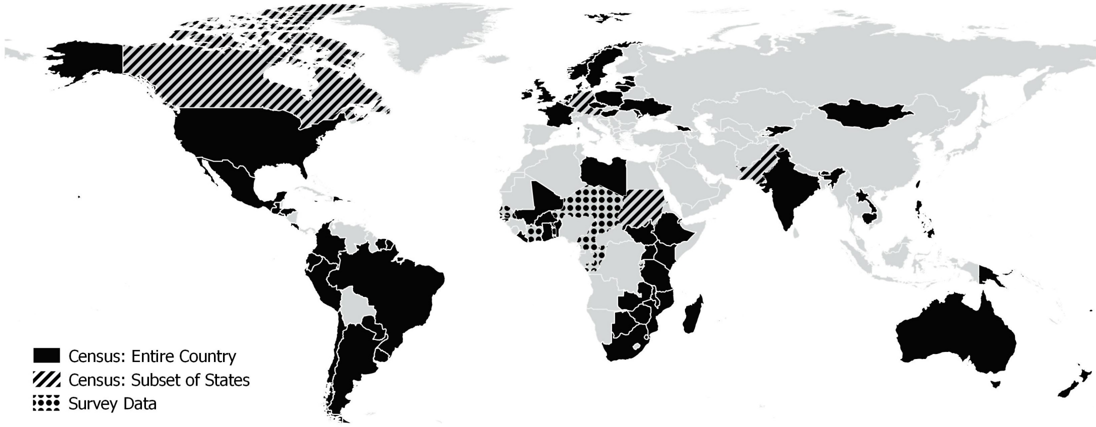
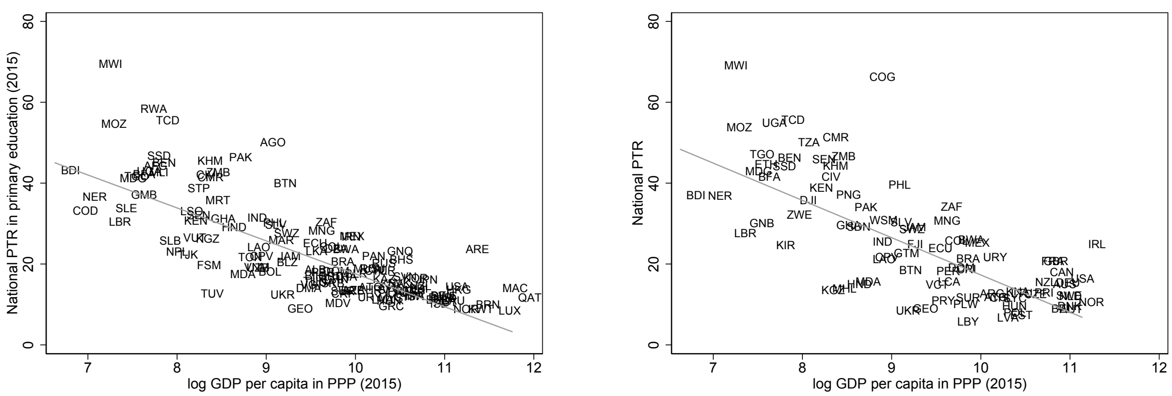


Figure 1: Data coverage

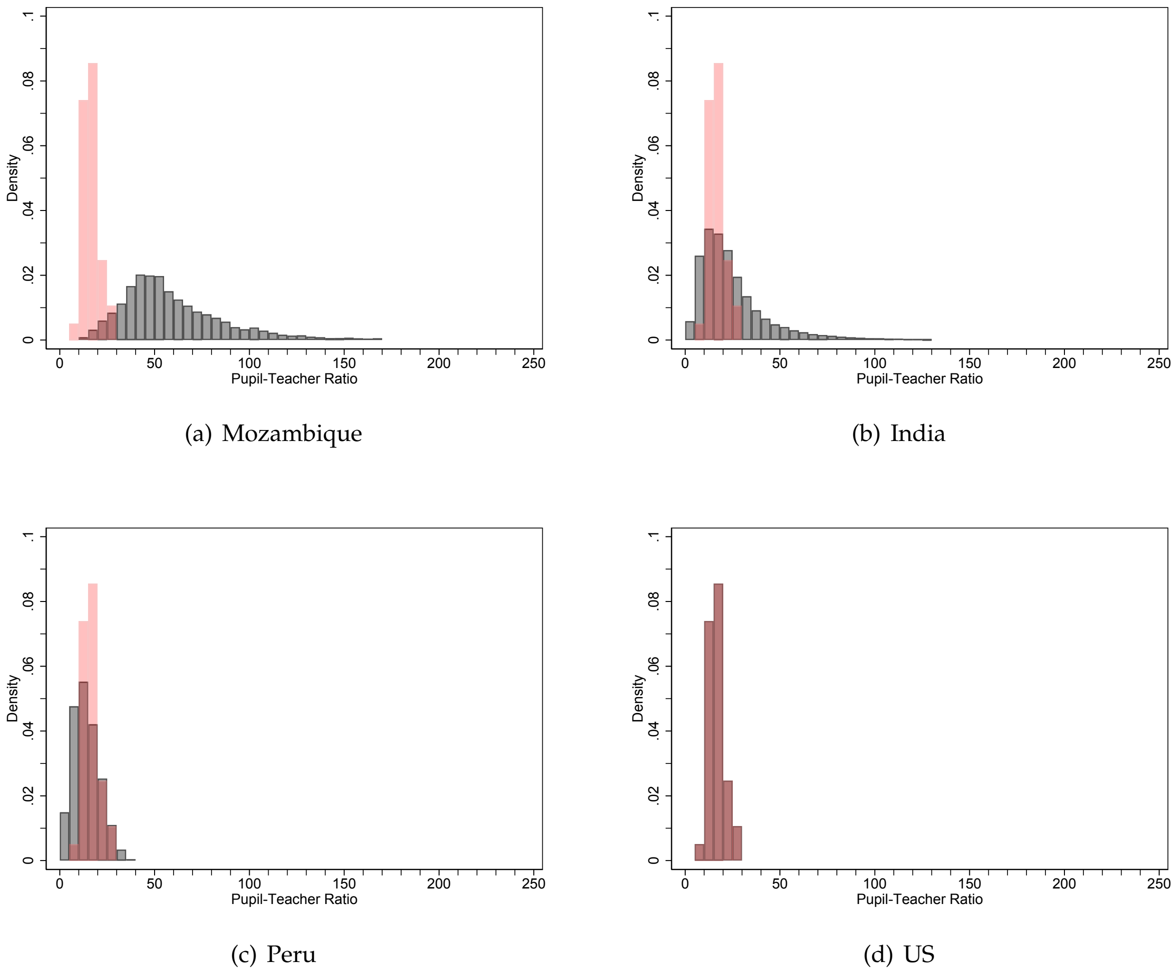


(a) Primary education (UIS)

(b) Public primary education (this paper)

Figure 2: National PTR in (public) primary education and income across countries

Grey lines are a linear regression lines. Panel A includes 131 countries. Panel B includes 90 countries. Note that it does not include the outlier Mali that has a national PTR of 182. Data sources: PTR data in Panel A is from the UNESCO Institute for Statistics (UIS). PTR data in Panel B is from this paper. GDP per capita data is from the World Bank International Comparison Program database.



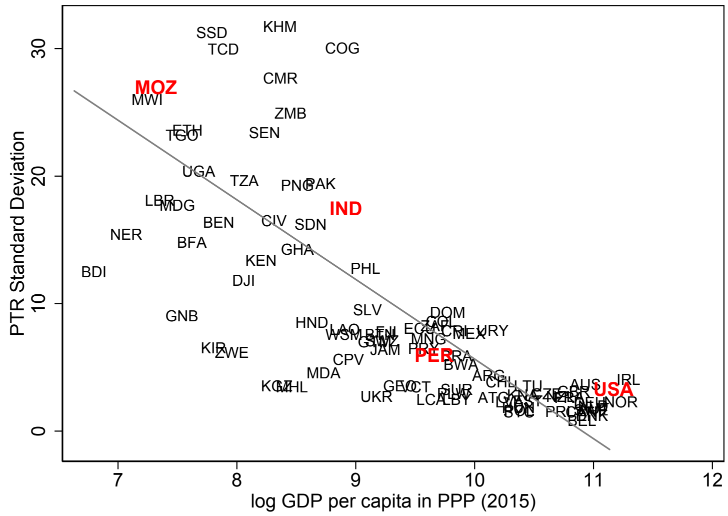
(a) Mozambique

(b) India

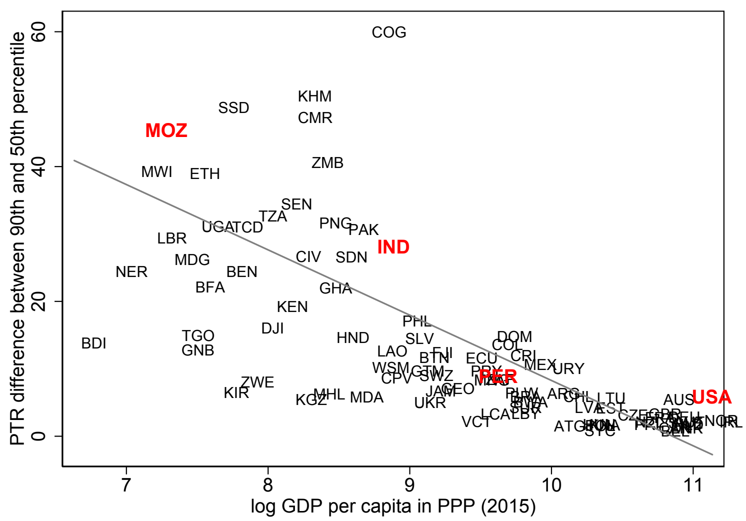
(c) Peru

(d) US

Figure 3: Distribution of PTRs across public primary schools in selected countries
Histograms show the distribution of PTRs across the universe of public primary schools in the selected countries. The US distribution is shown in shaded red in the background of all histograms.



(a) Standard deviation



(b) Length of right tail

Figure 4: PTR variation in public primary education and income across countries

Grey lines are linear regression lines. The four example countries are marked in red. The PTR standard deviation is defined as the standard deviation in PTRs across all public primary schools within a country. Note that this figure does not include the outlier Mali that has a PTR standard deviation of 104 and a difference of 171 between the 50th and the 90th percentile of the PTR distribution. GDP per capita data is from the World Bank International Comparison Program database.

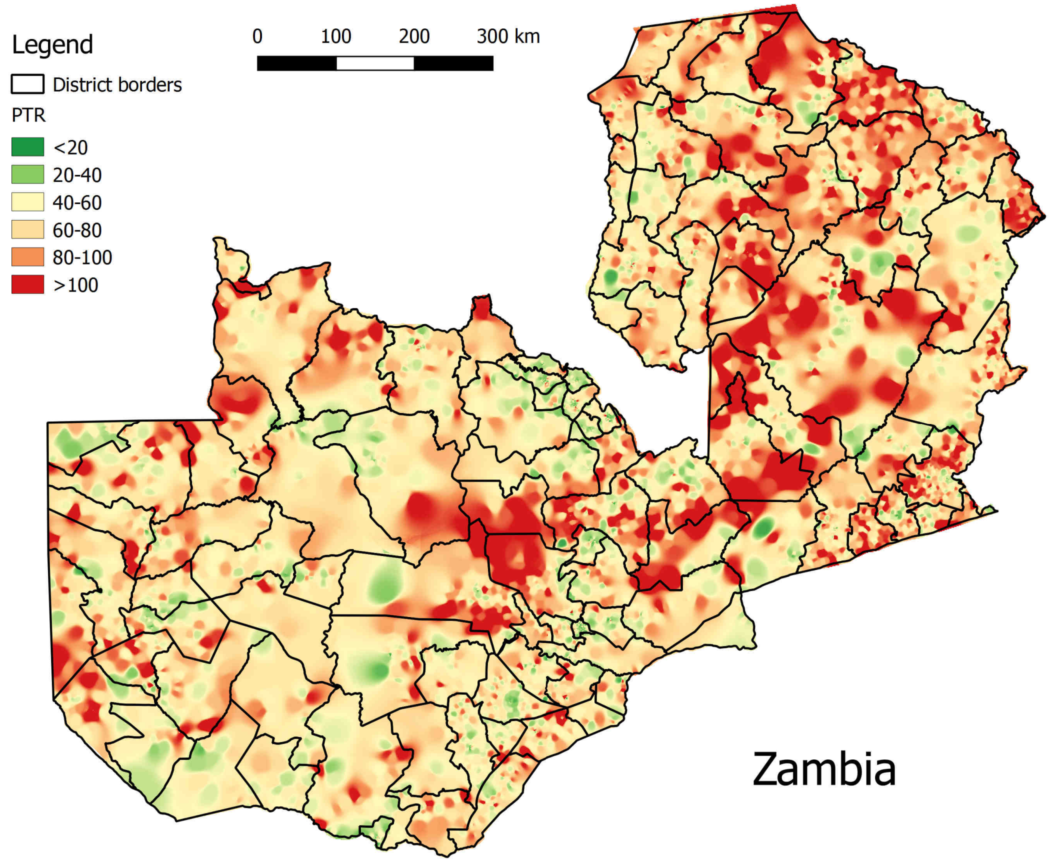
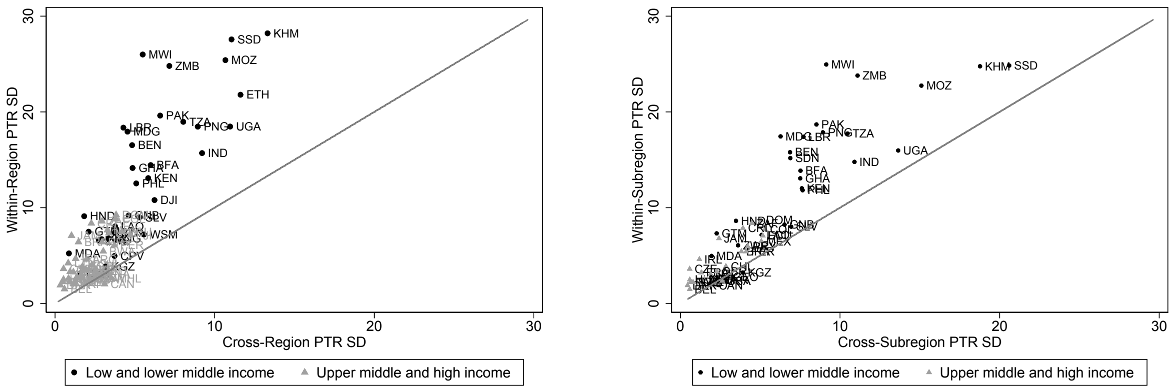


Figure 5: PTR heat map of Zambia

The heat map shows the spatial variation in PTRs across public primary schools in Zambia. The map indicates areas around schools with high PTRs in increasingly dark shades of red and areas around school with low PTRs with increasingly dark shades of green. The map is based on all public primary schools for which school coordinates were available. See table A.3 for details.

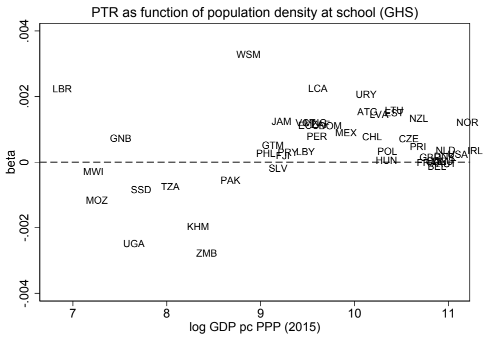


(a) Regions (admin level 1)

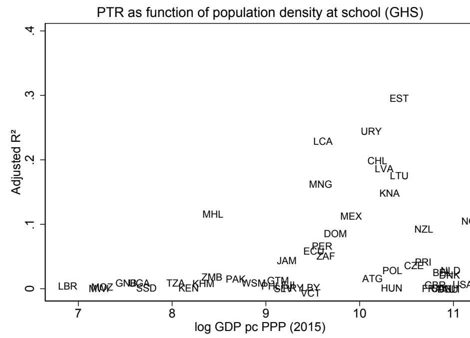
(b) Subregions (admin level 2)

Figure 6: PTR variation between and within subnational administrative units

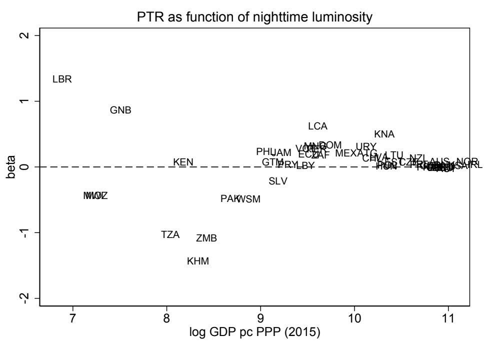
Grey lines are 45-degree lines. Regions and subregions are defined as detailed in table A.2. The sample in Panel A is comprised of 80 countries, the sample in Panel B of 56 countries. The underlying World Bank country income classification is from 2015.



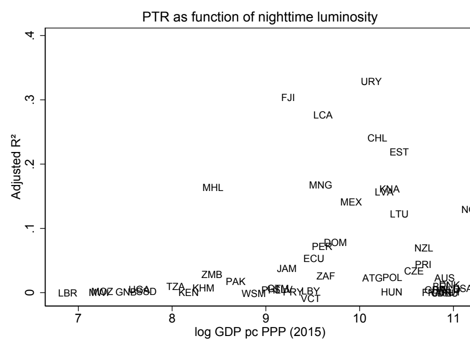
(a) Population density: Regression coefficient



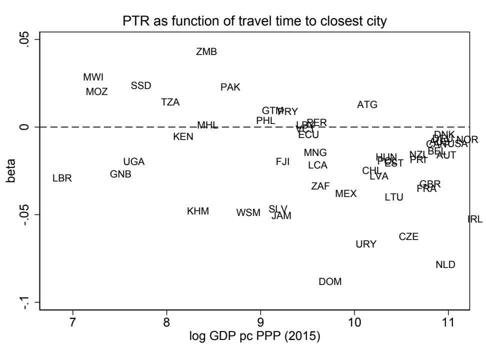
(b) Population density: Adjusted R^2



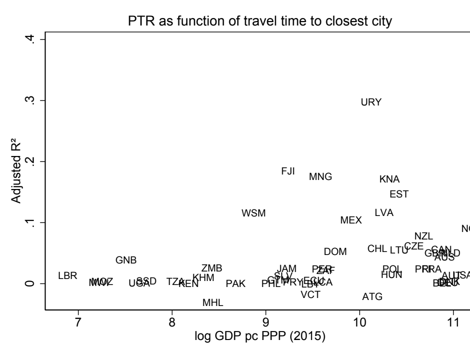
(c) Nighttime luminosity: Regression coefficient



(d) Nighttime luminosity: Adjusted R^2



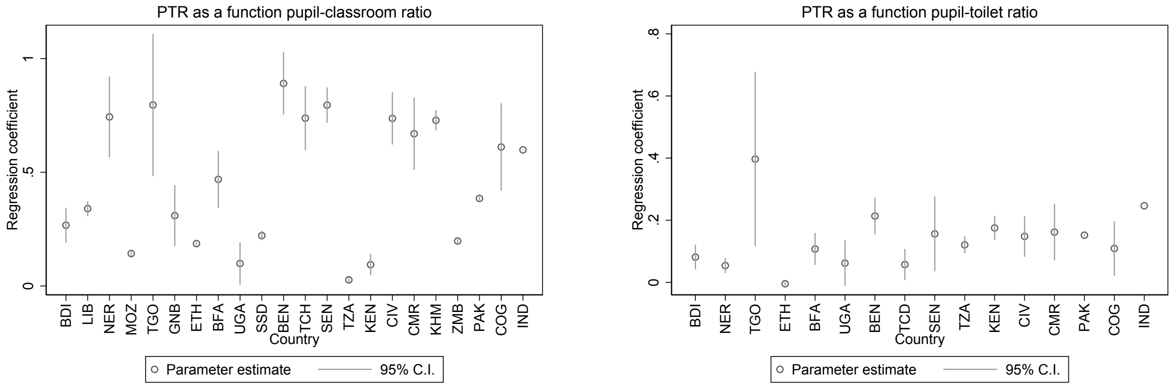
(e) Travel time to closest city: Regression coefficient



(f) Travel time to closest city: Adjusted R^2

Figure 7: PTRs and rurality across countries by income

In Panel A, beta is the regression coefficient from a country-specific school-level regression of PTR on population density (population per square kilometer) within a circle of 3km around the school as given by Global Human Settlement (GHS) data. Note that the three outliers of Kenya (beta of .035), the Marshall Islands (beta of .012) and in Saint Kitts and Nevis (beta of .009) are not displayed. In Panel B, beta is the regression coefficient from a country-specific school-level regression of PTR on nighttime luminosity in 2015 as given by the Earth Observation Group at the NOAA National Geophysical Data Center. Note that the four outliers Fiji (beta of 3.80), Marshall Islands (beta of 3.59), Uganda (beta of -3.31) and South Sudan (beta of -4.55) are not displayed. In Panel C, beta is the regression coefficient from a country-specific school-level regression of PTR on travel time to the closest city (minutes) in 2015 as given by Malaria Atlas Project (MAP). Note that the outlier of Saint Kitts and Nevis with a coefficient of .077 is not displayed. The sample for all three panels contains all 51 countries for which school coordinates were obtained. GDP per capita data is from the World Bank International Comparison Program database.



(a) Classrooms

(b) Toilets

Figure 8: PTRs and other school inputs

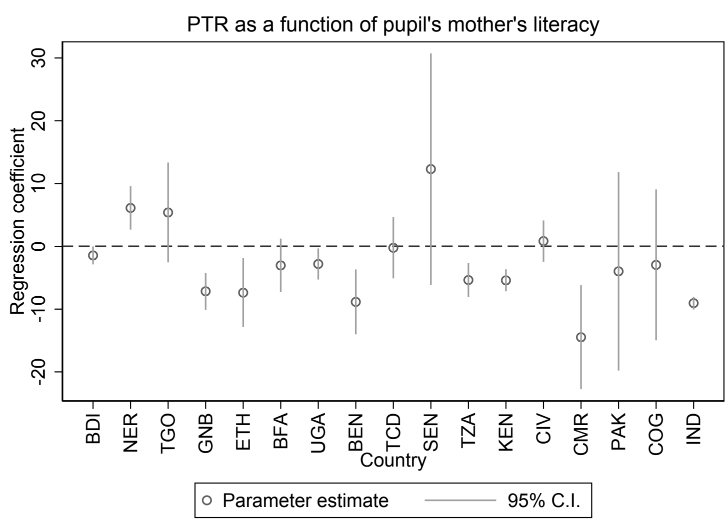
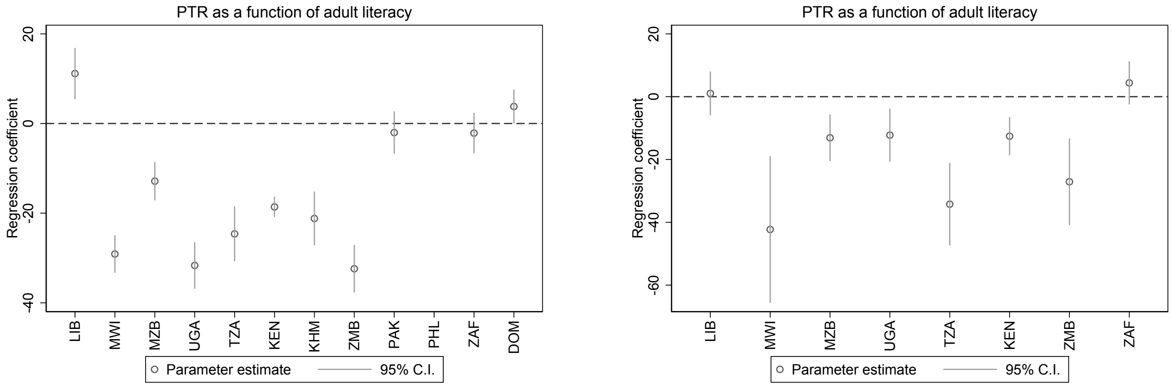


Figure 9: PTRs and pupils' mothers' education in developing countries

Regression coefficients are from country-specific school-level regressions of PTR on the literacy of pupils' mothers as given in various school surveys. Along the x-axis countries are ordered by GDP per capita (2015). See Table A.6 for a list of the underlying data sources. GDP per capita data is from the World Bank International Comparison Program database.



(a) Demographic Health Survey

(b) Afrobarometer

Figure 10: PTRs and parental education in developing countries
Regression coefficients are from country-specific school-level regressions of PTR on the local adult literacy rate as given by the latest Demographic Health Survey (DHS) and Afrobarometer, respectively. The sample is restricted to countries where public primary schools could be spatially matched with survey clusters. Along the x-axis countries are ordered by GDP per capita (2015). Table A.5 lists the utilized DHS survey waves. Afrobarometer data is from Round 6 of the survey. GDP per capita data is from the World Bank International Comparison Program database.

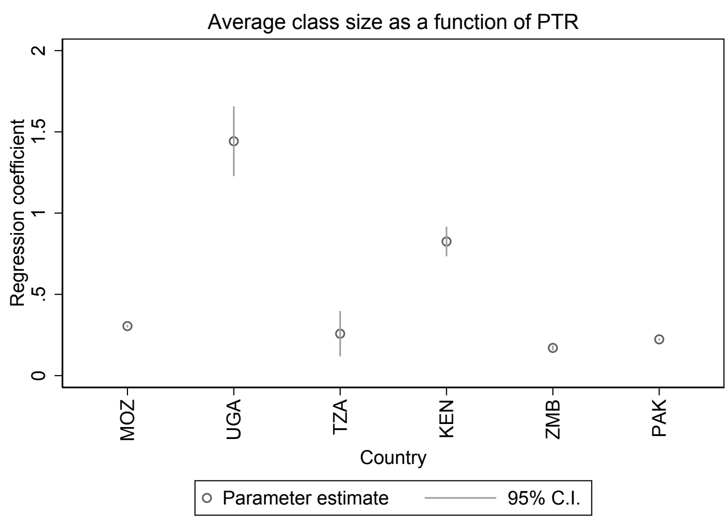
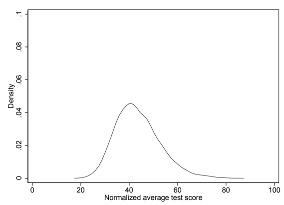
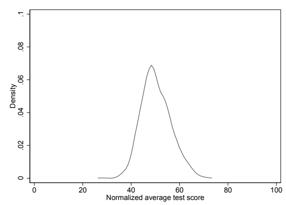


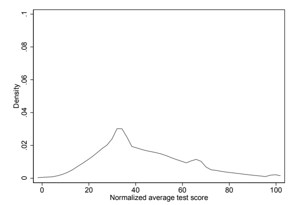
Figure 11: School-level PTRs and average class size in developing countries
Regression coefficients are from country-specific school-level regressions of mean class size on school-level as given in various annual school censuses and UWEZO school survey data. Along the x-axis countries are ordered by GDP per capita (2015). See Table A.7 for a list of the underlying data sources. GDP per capita data is from the World Bank International Comparison Program database.



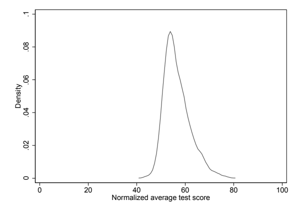
(a) Tanzania



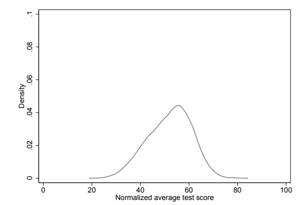
(b) Zambia



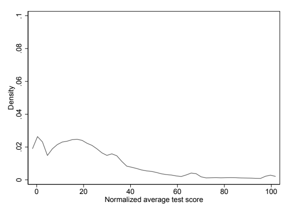
(c) India



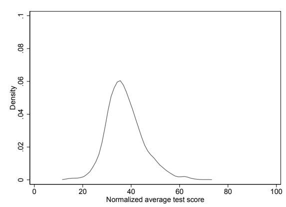
(d) Dominican Republic



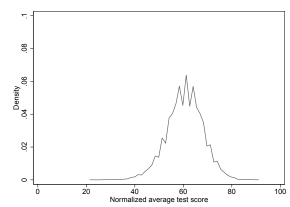
(e) Brazil



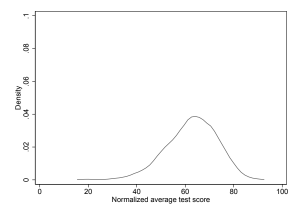
(f) Mexico



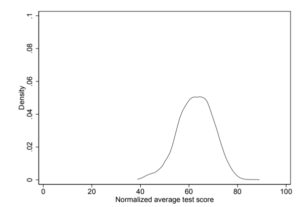
(g) Chile



(h) UK

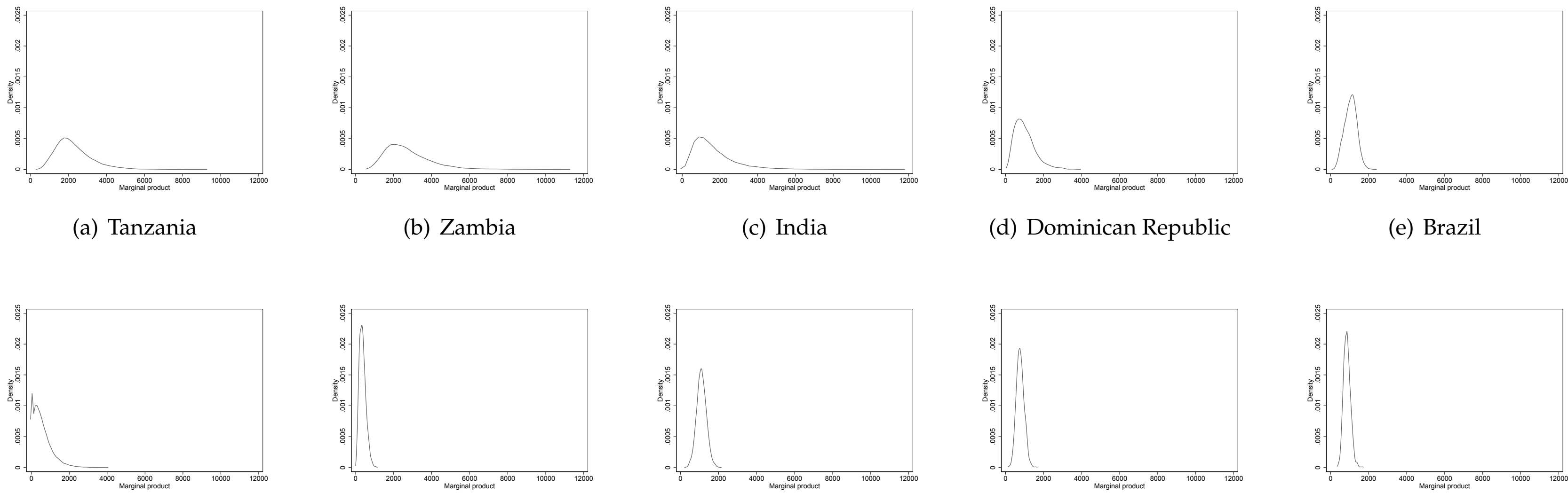


(i) Sweden



(j) US

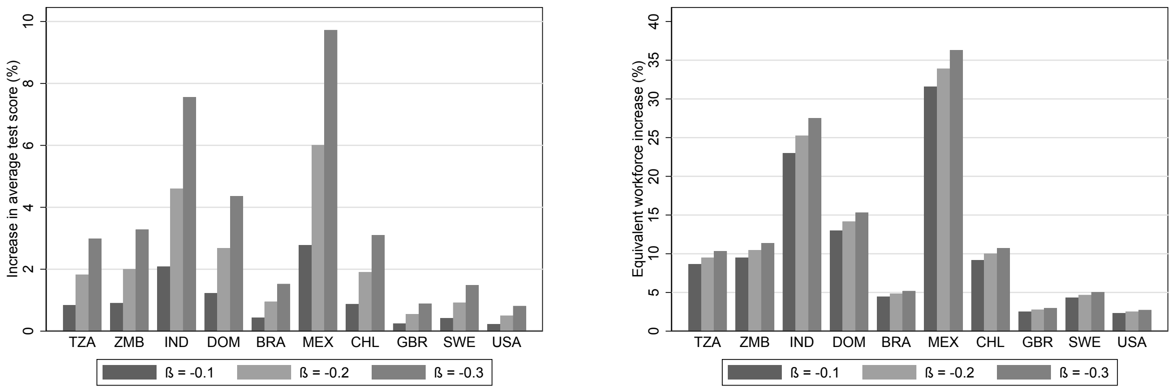
Figure 12: Distribution of normalized average exam scores across public primary schools



(a) Tanzania (b) Zambia (c) India (d) Dominican Republic (e) Brazil

(f) Mexico (g) Chile (h) UK (i) Sweden (j) US

Figure 13: Distribution of marginal products

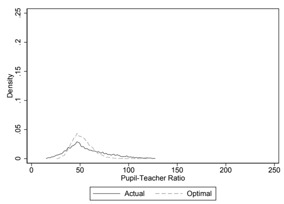


(a) Gains in average test score

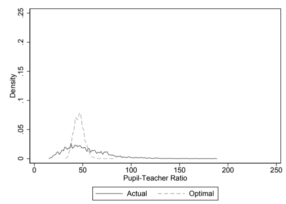
(b) Equivalent teacher workforce increases

Figure 14: Gains from optimal teacher allocation

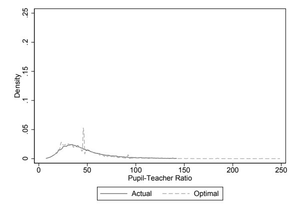
This figure shows the gains from the implementation of the optimal teacher allocation according to the model. Along the x-axis countries are ordered by GDP per capita (2015). GDP per capita data is from the World Bank International Comparison Program database.



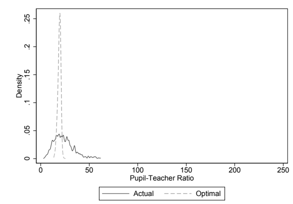
(a) Tanzania



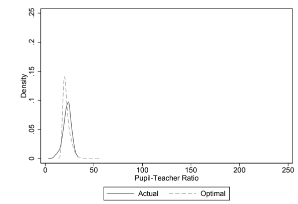
(b) Zambia



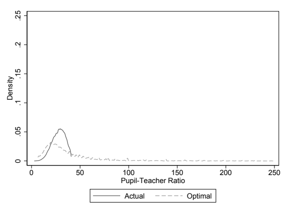
(c) India



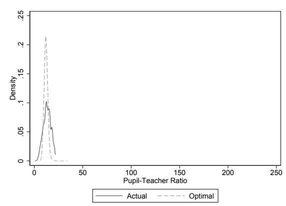
(d) Dominican Republic



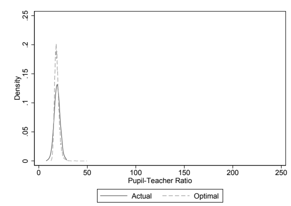
(e) Brazil



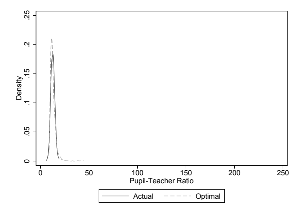
(f) Mexico



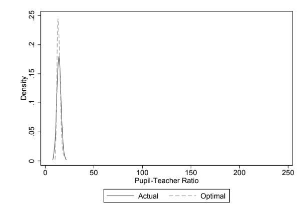
(g) Chile



(h) UK

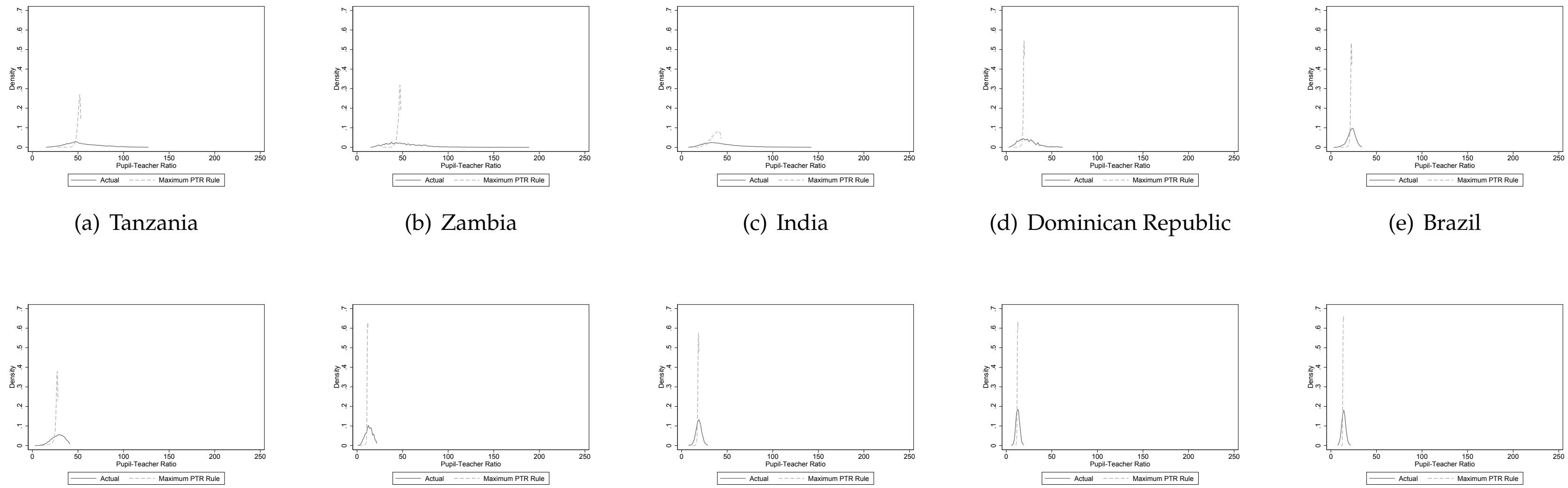


(i) Sweden



(j) US

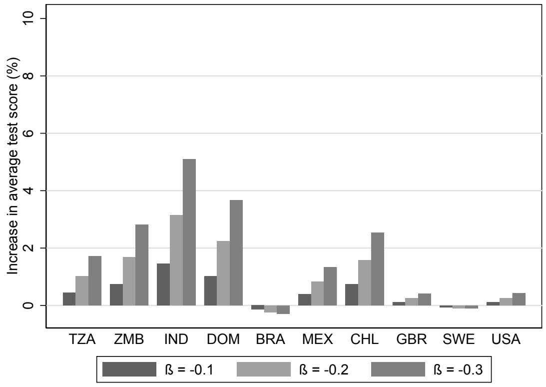
Figure 15: PTR distribution under optimal teacher allocation



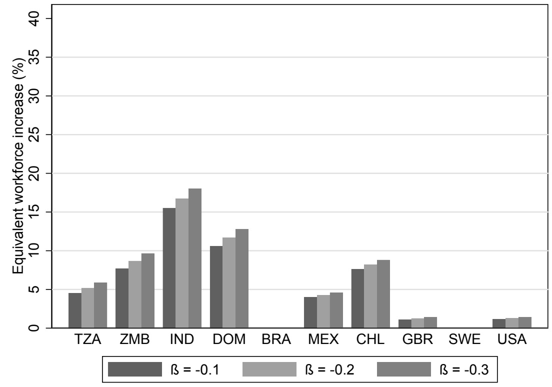
(a) Tanzania (b) Zambia (c) India (d) Dominican Republic (e) Brazil

(f) Mexico (g) Chile (h) UK (i) Sweden (j) US

Figure 16: PTR distribution under rule-based PTR equalization



(a) Gains in average test score



(b) Equivalent teacher workforce increases

Figure 17: Gains from rule-based PTR equalization

This figure shows the gains (losses) from the implementation of rule-based PTR equalization. Along the x-axis countries are ordered by GDP per capita (2015). GDP per capita data is from the World Bank International Comparison Program database.

Tables

Table 1: Data summary

Country	Data type	Year	School types (grades)	Schools	Pupils (K)	Teachers (K)
Antigua and Barbuda	Census	2010/11	PRIM (1-6)	30	5.1	0.4
Argentina	Census	2015	PRIM (1-6, 1-7)	18,408	3,482.3	273.6
Australia	Census	2016	PRIM (1-6)	4,735	1,437.3	95.6
Austria	Census*	2016/17	PRIM (1-4)	1,771	176.1	20.0
Belgium	Census*	2017	PRIM (1-6)	918	267.4	29.9
Benin	Census	2018	PRIM (1-6)	7,331	1,660.0	35.9
Bhutan	Census	2015	PRIM (1-6)	413	45.4	2.5
Botswana	Census	2009	PRIM (1-7)	707	298.4	11.5
Brazil	Census	2015	PRIM (1-8, 1-9)	79,805	22,132.3	1,040.3
Burkina Faso	Census	2017	PRIM (1-6)	11,537	2,429.0	58.4
Burundi	Survey	2014	PRIM (1-6)	165	102.8	2.6
Cambodia	Census	2014	PRIM (1-6)	6,164	1,784.0	40.6
Cameroon	Survey	2014	PRIM (1-6)	177	47.4	0.9
Canada	Census*	2014-16	PRIM (1-5, 1-8)	3,471	1,326.1	73.7
Cape Verde	Census	2014/15	PRIM (1-6)	407	63.6	2.9
Chad	Survey	2014	PRIM (1-6)	93	42.9	0.7
Chile	Census	2015	PRIM (1-8)	3,764	666.2	56.5
Colombia	Census	2015	PRIM (1-5)	39,953	3,488.8	40.0
Congo, Rep.	Survey	2014	PRIM (1-6)	81	35.0	0.4
Costa Rica	Census	2016	PRIM (1-6)	3,674	538.7	28.6
Cote d'Ivoire	Survey	2014	PRIM (1-6)	144	40.9	0.8
Czech Republic	Census	2017	PRIM (1-9)	3,900	886.8	70.4
Denmark	Census	2015/16	COMP (1-10, 1-11)	1,204	524.6	55.0
Djibouti	Census	2014/15	PRIM (1-5)	132	56.3	1.6
Dominican Republic	Census	2016/17	PRIM (1-6)	3,936	777.4	40.7
Ecuador	Census	2015/16	PRIM (1-7)	9,245	790.1	33.1

Table 1: Data summary

Country	Data type	Year	School types (grades)	Schools	Pupils (K)	Teachers (K)
El Salvador	Census	2013	PRIM (1-9)	4,224	912.1	30.1
Estonia	Census	2016	PRIM (1-3, 1-6)	415	79.7	10.5
Fiji	Census	2017	PRIM (1-6)	691	142.3	5.7
France	Census	2015/16	PRIM (1-5)	29,550	3,930.9	189.4
Georgia	Census	2016	COMP (1-12)	1,587	486.7	53.1
Germany	Census*	2014/15	PRIM (1-4)	2,017	389.8	28.5
Ghana	Census	2017/18	PRIM (1-6)	15,056	3,171.4	107.1
Guatemala	Census	2015	PRIM (1-3, 1-6, 4-6)	19,448	2,453.2	108.4
Guinea-Bissau	Census	2014	PRIM (1-4, 1-6)	694	170.7	5.7
Honduras	Census	2012	PRIM (1-6, 1-9)	11,440	1,192.8	79.4
Hungary	Census	2015/16	PRIM (1-8)	2,952	629.4	65.0
India	Census	2015	PRIM (1-5, 6-8, 1-8)	1,022,248	104,608.3	4,104.0
Ireland	Census	2015/16	PRIM (1-6)	3,124	541.0	31.8
Jamaica	Census	2015	PRIM (1-6)	377	136.0	4.7
Kenya	Survey	2014	PRIM (1-8)	4,135	2,373.6	68.6
Kiribati	Census	2011	PRIM (1-6)	94	15.5	0.6
Kyrgyzstan	Census	2015	COMP (1-11)	1,674	822.8	60.6
Laos	Census	2016/17	PRIM (1-5)	8,606	807.4	38.1
Latvia	Census	2016	PRIM (1-6) & BAS (1-9)	369	51.0	7.4
Liberia	Census	2015	PRIM (1-6) & BAS (1-9)	2,486	335.7	12.2
Libya	Census	2012	PRIM (1-6) & BAS (1-9)	3,194	1,005.4	175.9
Lithuania	Census	2016	PRIM (1-4) & BAS (1-10)	555	57.3	4.5
Madagascar	Census	2016	PRIM (1-5)	24,447	3,857.8	89.8
Malawi	Census	2016	PRIM (1-8)	5,404	4,703.5	68.4
Mali	Census	2017/18	PRIM (1-6) & BAS (1-9)	7,831	5,548.3	40.2
Marshall Islands	Census	2013/14	PRIM (1-8)	80	9.7	0.7

Table 1: Data summary

Country	Data type	Year	School types (grades)	Schools	Pupils (K)	Teachers (K)
Mexico	Census	2015/16	PRIM (1-6)	88,991	12,969.9	514.0
Moldova	Census	2016	PRIM (1-4) & BAS (1-9)	906	69.3	4.4
Mongolia	Census	2016	BAS (1-9) & COMP (1-12)	614	272.1	8.9
Mozambique	Census	2016	PRIM (1-5, 6-7, 1-7)	12,386	5,815.3	108.2
Netherlands	Census	2015/16	PRIM (1-8)	2,059	437.1	36.2
New Zealand	Census	2015	PRIM (1-5, 1-7, 6-7)	1,691	405.1	26.1
Niger	Survey	2014	PRIM (1-6)	166	61.8	1.5
Norway	Census	2016/17	PRIM (1-7)	2,114	429.4	40.6
Pakistan	Census*	2013-16	PRIM (1-5)	80,593	7,044.5	206.6
Palau	Census	2016	PRIM (1-6)	18	1.8	0.2
Papua New Guinea	Census	2016	PRIM (1-6)	4,264	732.9	19.8
Paraguay	Census	2013/14	PRIM (1-6, 1-9)	5,176	676.2	62.3
Peru	Census	2016	PRIM (1-6)	29,141	2,563.5	140.6
Philippines	Census	2013/14	PRIM (1-6)	37,948	14,952.8	377.5
Poland	Census	2017	PRIM (1-6)	9,577	2,675.3	331.1
Puerto Rico	Census	2014/15	PRIM (1-5, 1-6, 1-7, 1-8)	771	180.8	14.0
St Kitts and Nevis	Census	2013/14	PRIM (1-6)	24	4.3	0.3
St Lucia	Census	2014/15	PRIM (1-9)	74	15.8	1.0
St Vincent and the Grenadines	Census	2014/15	PRIM (1-6)	68	13.4	0.9
Samoa	Census	2015	PRIM (1-8)	143	33.7	1.1
Senegal	Survey	2014	PRIM (1-6)	134	68.6	1.4
Seychelles	Census	2012	PRIM (1-6)	24	10.4	0.9
South Africa	Census	2015	PRIM (1-7)	13,781	6,497.8	190.8
South Sudan	Census	2015	PRIM (1-8)	2,409	884.7	20.2
Sudan	Census*	2012	PRIM (1-8)	1,309	498.0	17.1
Suriname	Census	2016	PRIM (1-7)	333	69.6	5.9

Table 1: Data summary

Country	Data type	Year	School types (grades)	Schools	Pupils (K)	Teachers (K)
Swaziland	Census	2013	PRIM (1-7)	591	235.2	8.2
Sweden	Census	2015/16	PRIM (1-9)	3,982	838.4	68.8
Tanzania	Census	2016	PRIM (1-7)	14,598	7,489.3	172.5
Togo	Survey	2014	PRIM (1-6)	141	35.9	0.7
UK	Census	2015/16	PRIM (1-4)	20,118	5,289.6	255.1
US	Census	2014/15	PRIM (1-5, 1-6, 1-7, 1-8)	51,732	24,046.2	1,471.0
Uganda	Census	2016	PRIM (1-7)	11,357	6,702.4	122.4
Ukraine	Census	2013/14	COMP (1-10, 1-11)	16,370	3,771.4	443.0
Uruguay	Census	2015	PRIM (1-6)	1,953	247.8	11.4
Zambia	Census	2015	PRIM (1-7) & BAS (1-9)	5,790	2,864.1	62.0
Zimbabwe	Census	2018	PRIM (1-7)	5,285	2,404.2	74.8

The table indicates three different types of data: census, census*, and survey. Census means that data for the universe of public primary schools was collected. Census* indicates that data for the universe of public primary schools was collected from a subset of the highest administrative divisions in the country. See table A.1 for details. Survey indicates that the collected data is from a nationally representative school or household survey. Column (4) lists the included school types for each country and the typical grade range at these schools. PRIM stands for primary, BAS for basic, and COMP for comprehensive. Apart from the indicated grades, schools may also include pre-primary education. The last three columns provide information on the total number of schools, pupils and teachers contained in the data. Totals are computed after dropping schools for which PTR information was not available. See table A.1 for details on the share of public primary schools without PTR information.

A Appendix

A.1 Teacher indivisibility and PTR dispersion

National PTRs and cross-school PTR variation are strongly positively correlated. Since teachers are indivisible, this positive correlation could to some extent be mechanical because even if attempting to distribute an indivisible resource evenly across a given number of units, inequality across units increases as the resource becomes increasingly scarce. In order to assess the importance of this mechanical effect in the context of cross-school PTR variation, I carry out a series of simulations. I ask how large the PTR variation would be if cross-school PTR variation was minimized given the network of existing schools and the distribution of pupils across schools. Since minimizing the cross-school PTR variance is a computationally very challenging problem, I simplify the problem and apply a rule-of-thumb instead. I simulate the implementation of a maximum PTR rule in every country which says that the PTR may not exceed a given threshold in any school in the country[40]. For every country, I compute the smallest achievable threshold given the total stock of teachers and simulate the rule for this threshold.

Figure **??** plots the PTR in a school as a function of the size of the school (number of pupils). Two hypothetical scenarios are illustrated, one of a country with relatively few teachers and a threshold of 50 and one of a country with more teachers and a threshold of 25. It becomes clear that PTR variation will be larger in the country with the smaller stock of teacher given an identical school size distribution. In addition, there will be larger PTR variation in countries with smaller schools. While low-income countries have smaller stocks of teachers relative to the total number of pupils, they also tend to have larger schools. Hence, the mechanical variance-increasing effect of small teacher stocks is counteracted by the mechanical variance-decreasing effect of larger schools in developing countries. Results from the simulation are shown in figure A.22. The cross-school PTR standard deviation under the smallest achievable maximum PTR rule is indeed increasing in the national aggregate PTR, but relative to the increase of the actual PTR standard deviation the effect is small.

Note that these simulations do not take the distribution of pupils across grades into account and therefore abstract from problems of multigrade teaching that may arise when a maximum PTR rule is implemented. In fact, many governments employ one teacher per class (in primary education) and use a maximum class size rule to determine the number of classes. Results on the correlation between aggregate PTRs and PTR variation under such a rule (available upon request) show a stronger positive relationship between the two than under the maximum PTR rule. But again actual PTR variation under high aggregate PTRs is much larger than this counterfactual would suggest.

A.2 Appendix tables

[40] Such a rule is actually in place in India.

Table A.1: Core data sources

Country	State/Province	Data type	Collection method	Data source	Date obtained	Share w/o PTR
Antigua and Barbuda		Census	Download	Educational Statistical Digest 2012; Ministry of Education, Sports, Youth and Gender Affairs; Antigua and Barbuda; Retrieved from: http://www.education.gov.ag/#	07.08.2017	0%
Argentina		Census	Download	Direccion Nacional de Informacion y Estadistica Educativa; Ministerio de Educacion y Deportes; Argentina; Retrieved from: http://portales.educacion.gov.ar/diniece/2016/08/24/bases-de-datos-por-escuela-con-id/	22.01.2017	1%
Australia[41]		Census	Data request	Australian Curriculum, Assessment and Reporting Authority	25.04.2017	< 1%
Austria	Burgenland	Census	Data request	Landesschulrat fuer Burgenland	18.04.2017	0%
Austria	Niederoesterreich	Census	Data request	Landesschulrat fuer Niederoesterreich	25.04.2017	0%
Austria	Oberoesterreich	Census	Data request	Landesschulrat fuer Oberoesterreich	31.03.2017	0%
Austria	Steiermark	Census	Data request	Landesschulrat fuer Steiermark	02.05.2017	0%
Belgium	Flanders	Census	Data request	Education and Training; Flemish Community of Belgium	13.12.2017	0%
Benin		Census	Data request	Ministere de l'Enseignement Maternel et Primaire; Benin	06.07.2019	0%
Bhutan		Census	Download	Annual Education Statistics 2015; Ministry of Education; Royal Government of Bhutan; Retrieved from: http://www.education.gov.bt/statistic	22.01.2017	< 1%
Botswana		Census	Download	Ministry of Education and Skills Development; Botswana; Retrieved from: http://www.gov.bw/en/Ministries–Authorities/Ministries/Ministry-of-Education-and-Skills-Development/Schools/Public-Primary-Schools/	18.11.2016	< 1%
Brazil		Census	Download	Instituto Nacional de Estudos e Pesquisas Educacionais Anisio Teixeira; Ministerio da Educacao; Brazil; Retrieved from: http://dados.gov.br/dataset/microdados-do-censo-escolar	04.11.2016	0%
Burkina Faso		Census	Data request	Ministere de l'Education Nationale et de l'Alphabetisation, Burkina Faso	15.03.2018	0%
Burundi		Survey	Data request	Programme d'analyse des systemes educatifs de la confemen (PASEC) 2014	07.07.2017	N/A
Cambodia		Census	Download	Ministry of Education, Youth and Sports; Cambodia; Retrieved from: https://opendevelopmentcambodia.net/dataset/?id=school-of-cambodia-2012	28.03.2018	9%
Cameroon		Survey	Data request	Programme d'analyse des systemes educatifs de la confemen (PASEC) 2014	07.07.2017	N/A
Canada	New Brunswick	Census	Data request	Department of Education and Early Childhood Development; New Brunswick	15.06.2017	0%
Canada[42]	Ontario	Census	Data request	Ministry of Education; Ontario	20.06.2017	18%
Cape Verde		Census	Download	Anuario da Educacao 2014/2015; Ministerio da Educacao e Desporto; Cape Verde; Retrieved from: http://www.minedu.gov.cv/index.php?option=com_jdownloads&view=summary&id=913:anuario-da-educacao-ano-letivo-2014-2015&catid=4&Itemid=574	23.11.2016	5%
Chad		Survey	Data request	Programme d'analyse des systemes educatifs de la confemen (PASEC) 2014	07.07.2017	N/A
Chile		Census	Download	Centro de Estudios; Ministerio de Educacion; Gobierno de Chile; Retrieved from: http://centroestudios.mineduc.cl/tp_modulos/tpm_seccion/contVentana.php?cc=2179	07.11.2016	0%
Colombia		Census	Download		14.08.2018	1%
Congo, Rep.		Survey	Data request	Programme d'analyse des systemes educatifs de la confemen (PASEC) 2014	07.07.2017	N/A
Costa Rica		Census	Data request	Departamento de Anlisis Estadstico; Ministerio de Educacion Publica; Costa Rica	17.05.2017	0%
Cote d'Ivoire		Survey	Data request	Programme d'analyse des systemes educatifs de la confemen (PASEC) 2014	07.07.2017	N/A
Czech Republic		Census	Data request	Ministry of Education, Youth and Sports of the Czech Republic	07.04.2017	< 1%
Denmark		Census	Data request	Undervisningsministeriet; Styrelsen for It og Lring; Center for Data og Analyse; Denmark	18.09.2017	2%
Djibouti		Census	Download	Annuaire Statistique 2014-2015; Ministere de lEducation Nationale et de la Formation Professionnelle; Republique de Djibouti; Retrieved from: http://www.education.gov.dj/	09.01.2017	0%
Dominican Republic		Census	Data request	Instituto Dominicano de Evaluacion e Investigacion de la Calidad Educativa	13.04.2018	0%
Ecuador		Census	Data request	Ministerio de Educacion; Ecuador	03.03.2017	< 1%
El Salvador		Census	Download	Ministerio de Educacion; Republica de El Salvador; Retrieved from: https://www.mined.gob.sv/index.php/estadisticas-educativas/item/6116-bases-de-centros	11.12.2016	0%
Estonia		Census	Data request	Analysis Department; Estonian Ministry of Education and Research	24.04.2017	0%
Fiji		Census	Download	Ministry of Education; Fiji; Retrieved from: http://www.education.gov.fj/	07.04.2017	1%
France		Census	Download	Ministere de l'Education nationale, de l'Enseignement Superieur et de la Recherche; France; Retrieved from: https://data.education.gouv.fr/	23.01.2017	< 1%
Georgia		Census	Download	eCatalog; Education Management Information System; Georgia; Retrieved from: http://catalog.edu.ge/index.php?module=school_info&page=region_list	29.05.2017	0%
Germany	Hamburg	Census	Data request	Behoerde fuer Schule und Berufsbildung; Freie und Hansestadt Hamburg	15.05.2017	0%
Germany	Hessen	Census	Data request	Hessisches Kultusministerium	28.03.2017	0%

Table A.1: Core data sources

Country	State/Province	Data type	Collection method	Data source	Date obtained	Share w/o PTR
Germany	Schleswig-Holstein	Census	Data request	Ministerium fuer Schule und Berufsbildung des Landes Schleswig-Holstein	03.04.2017	0%
Germany	Thueringen	Census	Data request	Thueringer Ministerium fuer Bildung, Jugend, und Sport	20.03.2017	0%
Ghana		Census	Data request	Ministry of Education; Ghana	10.06.2019	< 1%
Guatemala		Census	Download	Direccion de Planificacion; Ministerio de Educacion; Guatemala; Retrieved from: http://estadistica.mineduc.gob.gt/BDD/	12.11.2016	4%
Guinea-Bissau		Census	Data request	Ministerio da Educacao e do Ensino Superior; Guinea-Bissau	11.12.2017	6%
Honduras		Census	Download	Unidad de Planeamiento y Evaluacion la Gestion; Secretaria de Educacion de Honduras; Retrieved from: http://estadisticas.se.gob.hn/see/archivos_descargables.php	18.12.2017	0%
Hungary[43]		Census	Data request	Hungarian Central Statistical Office	06.03.2017	< 1%
India		Census	Data request	District Information System for Education; National University of Educational Planning and Administration; India	24.11.2016	1%
Ireland		Census	Download	Department of Education and Skills; Ireland; Retrieved from: http://www.education.ie/en/Publications/Statistics/Data-on-Individual-Schools/Data-on-Individual-Schools.html	17.11.2016	0%
Jamaica		Census	Data request	Ministry of Education, Jamaica	24.02.2017	0%
Kenya		Survey	Download	UWEZO; Retrieved from: http://www.uwezo.net/publications/datasets/	21.03.2017	N/A
Kiribati		Census	Download	Digest of Education Statistics 2011; Ministry of Education; Republic of Kiribati; Retrieved from: http://prism.spc.int/reports/education	25.11.2016	0%
Kyrgyzstan		Census	Download	Ministry of Education and Science of the Kyrgyz Republic; Retrieved from: http://edu.gov.kg/ru/docs/statistics/	07.02.2017	< 1%
Laos		Census	Data request	Ministry of Education and Sports; Lao People's Democratic Republic	10.04.2018	0%
Latvia		Census	Data request	Ministry of Education and Science of the Republic of Latvia	21.03.2017	0%
Liberia		Census	Download	Ministry of Education; Republic of Liberia; Retrieved from: http://moe.gov.lr/documents/	06.12.2017	5%
Libya		Census	Download	Libya National Schools Assessment 2012; REACH Initiative; Retrieved from: https://data.humdata.org/dataset/reach-libya-national-schools-assessment-2012	13.02.2017	11%
Lithuania		Census	Data request	Ministry of Education and Science of the Republic of Lithuania	06.03.2017	0%
Madagascar		Census	Data request	Madagascar Ministere de l'Education Nationale	11.03.2017	< 1%
Malawi		Census	Data request	Ministry of Education; Malawi	21.03.2017	0%
Mali		Census	Data request	Ministere de l'Education Nationale et de l'Alphabetisation; Mali	13.08.2019	0%
Marshall Islands		Census	Download	Education Digest 2013-2014; Ministry of Education; Republic of the Marshall Islands; Retrieved from: http://prism.spc.int/reports/education	25.11.2016	0%
Mexico		Census	Download	Sistema Nacional de Informacion de Escuelas; Secretaria de Educacion Publica; Mexico; Retrieved from: http://www.snie.sep.gob.mx/SNIESC/	02.10.2017	2%
Moldova		Census	Data request	National Bureau of Statistics of the Republic of Moldova	10.05.2017	0%
Mongolia		Census	Data request	National Statistical Office of Mongolia	12.01.2017	4%
Mozambique		Census	Data request	Ministerio da Educacao e Desenvolvimento Humano; Republica da Mocambique	08.05.2017	0%
Netherlands		Census	Download	Dienst Uitvoering Onderwijs; Ministerie van OCW; Retrieved from: https://www.duo.nl/open_onderwijsdata/databestanden/po/	06.02.2017	< 1%
New Zealand		Census	Download	Education Counts; Ministry of Education; New Zealand Government; Retrieved from: http://www.educationcounts.govt.nz/statistics/schooling/	02.11.2016	< 1%
Niger		Survey	Data request	Programme d'analyse des systemes educatifs de la confemen (PASEC) 2014	07.07.2017	N/A
Norway		Census	Data request	Norwegian Directorate for Education and Training; Department of Statistics	08.02.2017	< 1%
Pakistan	Balochistan	Census	Download	Balochistan EMIS; Retrieved from: http://emis.gob.pk/views/Reports/Reports/SchoolSearchPublic.aspx	02.09.2018	12%
Pakistan	Punjab	Census	Download	Department of School Education; Government of Punjab; Retrieved from: http://www.pesrp.edu.pk/datacenter#district_ranking	19.05.2017	3%
Pakistan	Sindh	Census	Download	Education and Literacy Department; Government of Sindh; Retrieved from: http://www.rsu-sindh.gov.pk/downloads/schoolSearch.php	23.05.2017	< 1%
Palau		Census	Download	2011 Statistical Yearbook; Ministry of Education; Republic of Palau; Retrieved from: http://prism.spc.int/reports/education	25.05.2018	0%
Papua New Guinea		Census	Download	Department of Education; Papua New Guinea; Retrieved from: http://www.education.gov.pg/quicklinks/wms/school-profile.html	06.12.2016	< 1%
Paraguay		Census	Download	Ministerio de Educacion y Ciencias; Paraguay; Retrieved from: http://datos.mec.gov.py/data	24.01.2017	16%
Peru		Census	Download	Censo Escolar 2016; Ministerio de Educacion; Peru; Retrieved from: http://escale.minedu.gob.pe/uee/-/document_library_display/GMv7/view/2979785	07.11.2016	0%

Table A.1: Core data sources

Country	State/Province	Data type	Collection method	Data source	Date obtained	Share w/o PTR
Philippines		Census	Download	Department of Education; Republic of the Philippines; Retrieved from: http://www.deped.gov.ph/datasets	22.11.2016	2%
Poland		Census	Download	Centrum Informatyczne Edukacji; Poland; Retrieved from: https://cie.men.gov.pl/sio-strona-glowna/podstawowe-informacje-dotyczce-wykazu-szko-i-placowek-owiatowych/wykaz-wg-typow/	29.01.2018	26%
Puerto Rico		Census	Download	U.S. Department of Education; National Center for Education Statistics; Common Core of Data (CCD); Public Elementary/Secondary School Universe Survey CCD School Data 2014-15; Retrieved from: http://nces.ed.gov/ccd/	10.07.2017	$<1\%$
Saint Kitts and Nevis		Census	Download	Statistical Digest 2013-2014; St. Kitts and Nevis Ministry of Education; Retrieved from: http://www.moeskn.org/	08.12.2016	0%
Saint Lucia		Census	Download	Education Statistical Digest 2015; Ministry of Education, Human Resource Development and Labour; Government of St. Lucia; Retrieved from: http://education.govt.lc/publications/	08.12.2016	0%
Saint Vincent and the Grenadines		Census	Download	Education Statistical Digest of St. Vincent & the Grenadines 2014-2015; Retrieved from: http://www.education.gov.vc/education/	25.05.2018	0%
Samoa		Census	Download	Education Statistical Digest 2015; Ministry of Education, Sports, and Culture; Samoa; Retrieved from: http://prism.spc.int/reports/education	25.11.2016	0%
Senegal		Survey	Data request	Programme d'analyse des systemes educatifs de la confemen (PASEC) 2014	07.07.2017	N/A
Seychelles		Census	Download	Education Statistics 2012; Ministry of Education; Republic of Seychelles; Retrieved from: http://www.education.gov.sc/Pages/statistics.aspx	24.11.2016	0%
South Africa		Census	Download	Education Management Information System; National Department of Basic Education; South Africa; Retrieved from: http://www.education.gov.za/Programmes/EMIS.aspx	02.11.2016	4%
South Sudan		Census	Download	Education Management Information System; South Sudan; Retrieved from: http://www.southsudanemis.org/data	04.11.2016	$<1\%$
Sudan	Karthoum	Census	Download	Ministry of Education; Sudan; Retrieved from: http://moekh.gov.sd/	10.02.2017	23%
Suriname		Census	Data request	Ministerie van Onderwijs, Wetenschap un Cultuur; Suriname	23.08.2017	$<1\%$
Swaziland		Census	Data request	Ministry of Education and Training; Swaziland	30.11.2016	0%
Sweden		Census	Download	SiRiS; National Agency for Education; Sweden; Retrieved from: http://siris.skolverket.se/siris/	25.05.2018	$<1\%$
Tanzania		Census	Download	President's Office; Regional Administration and Local Government; The United Republic of Tanzania; Retrieved from: http://opendata.go.tz/dataset/uwiano-wa-mwalimu-kwa-wanafunzi-kwa-shule-za-msingi-za-serikali-2016	04.11.2016	9%
Togo		Survey	Data request	Programme d'analyse des systemes educatifs de la confemen (PASEC) 2014	07.07.2017	N/A
Uganda		Census	Data request	Ministry of Education and Sports; The Republic of Uganda	23.08.2017	$<1\%$
UK	England	Census	Download	Department for Education; England; Retrieved from: https://data.gov.uk/dataset/	07.02.2017	$<1\%$
UK	Northern Ireland	Census	Download	Department for Education; Northern Ireland; Retrieved from: https://www.education-ni.gov.uk/articles/	07.02.2017	0%
UK	Scotland	Census	Download	Scottish Government; Retrieved from: http://www.gov.scot/Topics/Statistics/Browse/School-Education/	07.02.2017	$<1\%$
UK	Wales	Census	Download	StatsWales; Retrieved from: https://statswales.gov.wales/Catalogue/Education-and-Skills/Schools-and-Teachers/Schools-Census/Pupil-Level-Annual-School-Census/	07.02.2017	0%
Ukraine		Census	Download	School Map of Ukraine; Retrieved from: http://cedos.org.ua/edustat/databox	29.01.2017	1%
Uruguay		Census	Download	Administracion Nacional de Educacion Publica; Uruguay; Retrieved from: http://www.anep.edu.uy/portalmonitor/servlet/buscarescuela	12.03.2018	$<1\%$
US		Census	Download	U.S. Department of Education; National Center for Education Statistics; Common Core of Data (CCD); Public Elementary/Secondary School Universe Survey CCD School Data 2014-15; Retrieved from: http://nces.ed.gov/ccd/	10.07.2017	1%
Zambia		Census	Data request	Ministry of Education; Zambia	14.06.2016	12%
Zimbabwe		Census	Data request	Ministry of Primary and Secondary Education; Zimbabwe	06.11.2019	0%

This table lists the data sources for the core data for all countries. In the last column, it also indicates the share of public primary schools for which the PTR could not be computed due to missing information. This is computed as the number of public primary school without PTR information over the total number of public primary schools listed. It is possible that for a given country the obtained list of public primary schools itself is incomplete. In this case the indicated share of schools for which the PTR could not be computed is an underestimate of the true share without PTR information.

[41]Disclaimer: The data used in this publication are sourced from the Australian Curriculum, Assessment and Reporting Authority (ACARA) and are available from ACARA in accordance with its Data Access Protocols.

[42]PTR information for schools with less than 10 teacher FTEs was not available. This accounts entirely for the share of schools without PTR information.

[43] Disclaimer: Results for Hungary have been created with the use of WTorsten_cimlista_altisk_tan_ped_2015-16.xlsx Datafile prepared upon individual request by the Hungarian Central Statistical Office (www.ksh.hu). The calculations and the conclusion are the sole intellectual products of the author Torsten Figueiredo Walter.

Table A.2: Regions and subregions

Country	Region definition	Regions	Subregion definition	Subregions
Antigua and Barbuda	Education Zone	4	N/A	N/A
Argentina	Province	24	N/A	N/A
Australia	State	8	N/A	N/A
Austria	State (NUTS-2)	4	Groups of Municipalities (NUTS-3)	25
Belgium	Province (NUTS-2)	6	Arrondissements (NUTS-3)	23
Benin	Departement	12	Commune	77
Bhutan	Dzongkhag	20	N/A	N/A
Botswana	District	14	N/A	N/A
Brazil	State	27	Municipality	5556
Burkina Faso	Region	13	Province	45
Cambodia	Province	24	District	186
Canada	Province	2	County/District	66
Cape Verde	Concelho	22	N/A	N/A
Chile	Region	13	Province	53
Colombia	Department	33	Municipality	1118
Costa Rica	Province	7	Canton	81
Czech Republic	Oblast (NUTS-2)	8	Regions (NUTS-3)	14
Denmark	Region (NUTS-2)	5	Province (NUTS-2)	11
Djibouti	Region	6	N/A	N/A
Dominican Republic	Region	10	Province	32
Ecuador	Province	25	Canton	216
El Salvador	Department	14	Municipality	255
Estonia	Group of counties (NUTS-3)	5	County (LAU-1)	15
Fiji	Group of districts	9	N/A	N/A
France	Region (NUTS-2)	25	Department (NUTS-3)	99
Georgia	Region	12	Municipality	69
Germany	State (NUTS-1)	4	District (NUTS-3)	67
Ghana	Region	10	District	216
Guatemala	Region	8	Department	23
Guinea-Bissau	Region	9	Sector	42
Honduras	Department	18	Municipality	269
Hungary	Planning and statistical region (NUTS-2)	7	County (NUTS-3)	20
India	State	35	District	679
Ireland	NUTS-2 Statistical Regions	2	NUTS-3 Statistical Regions	8
Jamaica	County	3	Parish	14
Kiribati	District	4	N/A	N/A
Kyrgyzstan	Region	8	District	59
Laos	Province	18	District	145
Latvia	Statistical Regions (NUTS-3)	6	District (LAU-1)	33
Liberia	County	15	District	99
Libya	District	23	N/A	N/A
Lithuania	County (NUTS-3)	10	N/A	N/A
Madagascar	Province	6	Region	22
Malawi	Region	3	District	34
Mali	Region	9	Cercle	47
Marshall Islands	Municipality	24	N/A	N/A
Mexico	State	32	Municipality	2316
Moldova	Region	5	District	35
Mongolia	Province	22	N/A	N/A
Mozambique	Province	11	District	160
Netherlands	Province (NUTS-2)	12	N/A	N/A
New Zealand	Region	16	District	86
Norway	Region	7	County (NUTS-3)	19
Pakistan	Province	3	District	91
Palau	N/A	N/A	N/A	N/A
Papua New Guinea	Province	20	District	88
Paraguay	Department	18	District	254
Peru	Region	25	Province	196
Philippines	Region	17	Province	83
Poland	Voivodeship (NUTS-2)	16	Subregions (NUTS-3)	72
Puerto Rico	Municipality	77	N/A	N/A
Saint Kitts and Nevis	Island	2	N/A	N/A
Saint Lucia	District	8	N/A	N/A
Saint Vincent and the Grenadines	District	11	N/A	N/A
Samoa	District	9	N/A	N/A
Seychelles	N/A	N/A	N/A	N/A
South Africa	Province	9	District	52
South Sudan	State	10	District	38
Sudan	State	1	District	6
Suriname	District	10	N/A	N/A
Swaziland	N/A	N/A	N/A	N/A
Sweden	National area (NUTS-2)	8	County (NUTS-3)	21
Tanzania	Region	25	District	180

Table A.2: Regions and subregions

Country	Region definition	Regions	Subregion definition	Subregions
Uganda	Region	4	District	118
UK	NUTS-2 Statistical Regions	39	NUTS-3 Statistical Regions	168
Ukraine	Oblast	27	Raion	626
Uruguay	Department	19	N/A	N/A
US	State	51	County	1849
Zambia	Province	10	District	103
Zimbabwe	Province	10	District	72

This table shows the definition of a region used throughout this paper for every country and the number of these regions contained in the data. The table does not contain countries for which survey data was collected as sample sizes in those countries are two small for a meaningful breakdown across sub-national units. For Swaziland, information on school location was not available. For Palau and Seychelles, information on the administrative divisions in which schools are located was not gathered as the total number of schools in these countries is very small.

Table A.3: GPS coordinates data sources

Country	State/Province	Data type	Collection method	Data source	Date obtained	Completeness	Shared coordinates
Antigua and Barbuda	-	Address	Download	Educational Statistical Digest 2012; Ministry of Education, Sports, Youth and Gender Affairs; Antigua and Barbuda; Retrieved from: http://www.education.gov.ag/	07.08.2017	100%	0%
Australia	-	Coordinates	Data request	Australian Curriculum, Assessment and Reporting Authority	25.04.2017	100%	< 1%
Austria	Burgenland	Address	Data request	Landesschulrat fuer Burgenland	18.04.2017	100%	6%
Austria	Niederoesterreich	Address	Data request	Landesschulrat fuer Niederoesterreich	25.04.2017	100%	2%
Austria	Oberoesterreich	Address	Data request	Landesschulrat fuer Oberoesterreich	31.03.2017	100%	2%
Austria	Steiermark	Address	Download	Schulendatei Online; Bundesministerium fuer Bildung, Wissenschaft und Forschung; Retrieved from: https://www.schulen-online.at/	25.08.2017	100%	0%
Belgium	Flanders	Coordinates	Data request	Education and Training; Flemish Community of Belgium	13.12.2017	100%	< 1%
Cambodia	-	Coordinates	Download	Ministry of Education, Youth and Sports; Cambodia; Retrieved from: https://opendevelopmentcambodia.net/dataset/?id=school-of-cambodia-2012	02.10.2017	100%	1%
Canada	New Brunswick	Address	Data request	Department of Education and Early Childhood Development; New Brunswick	15.06.2017	99%	0%
Canada	Ontario	Address	Data request	Ministry of Education; Ontario	20.06.2017	100%	< 1%
Chile	-	Coordinates	Download	Centro de Estudios; Ministerio de Educacion; Gobierno de Chile; Retrieved from: http://centroestudios.mineduc.cl/tp_modulos/tpm_seccion/contVentana.php?cc=2179	07.11.2016	100%	2%
Czech Republic	-	Coordinates	Data request	Ministry of Education, Youth and Sports of the Czech Republic	07.04.2017	100%	1%
Denmark	-	Address	Data request	Undervisningsministeriet; Styrelsen for It og Lring; Center for Data og Analyse; Denmark	18.09.2017	100%	< 1%
Dominican Republic	-	Coordinates	Data request	Instituto Dominicano de Evaluacion e Investigacion de la Calidad Educativa	13.04.2018	99%	< 1%
Ecuador	-	Coordinates	Data request	Ministerio de Educacion; Ecuador	03.03.2017	96%	2%
El Salvador	-	Coordinates	Download	Ministerio de Educacion; Republica de El Salvador; Retrieved from: https://www.mined.gob.sv/index.php/estadisticas-educativas/item/6116-bases-de-centros	11.12.2016	99%	2%
Estonia	-	Coordinates	Data request	Analysis Department; Estonian Ministry of Education and Research	24.04.2017	100%	0%
Fiji	-	Coordinates	Download	Ministry of Education; Fiji; Retrieved from: http://www.education.gov.fj/	06.03.2018	98%	< 1%
France	-	Coordinates	Download	Ministere de l'Education Nationale, de l'Enseignement Superieur et de la Recherche; France; Retrieved from: https://data.education.gouv.fr/	23.01.2017	100%	1%
Germany	Hamburg	Address	Data request	Behoerde fuer Schule und Berufsbildung; Freie und Hansestadt Hamburg	15.05.2017	100%	1%
Germany	Hessen	Address	Data request	Hessisches Kultusministerium	28.03.2017	100%	0%
Germany	Schleswig-Holstein	Address	Data request	Ministerium fuer Schule und Berufsbildung des Landes Schleswig-Holstein	03.04.2017	100%	< 1%
Germany	Thueringen	Address	Data request	Thueringer Ministerium fuer Bildung, Jugend, und Sport	20.03.2017	100%	< 1%
Guatemala	-	Coordinates	Download	Ministerio de Educacion; Guatemala; Retrieved from: http://www.mineduc.gob.gt/ie/Ministerio de Educacion; Guatemala; Retrieved from: http://www.mineduc.gob.gt/ie/	12.11.2016	47%	15%
Guinea-Bissau	-	Coordinates	Data request	Ministerio da Educacao e do Ensino Superior; Guinea-Bissau	29.09.2017	99%	< 1%
Hungary[44]	-	Address	Data request	Hungarian Central Statistical Office	06.03.2017	100%	1%
Ireland	-	Coordinates	Download	Department of Education and Skills; Ireland; Retrieved from: http://www.education.ie/en/Publications/Statistics/Data-on-Individual-Schools/Data-on-Individual-Schools.html	25.04.2018	99%	2%
Jamaica	-	Coordinates	Data request	Ministry of Education, Jamaica	24.02.2017	100%	1%
Latvia	-	Address	Data request	Ministry of Education and Science of the Republic of Latvia	21.03.2017	97%	2%
Liberia	-	Coordinates	Download	FHI360; Retrieved from: http://fhi360odk.org/kdesktoplb_2/	14.10.2017	65%	0%
Libya	-	Coordinates	Download	Libya National Schools Assessment 2012; REACH Initiative; Retrieved from: https://data.humdata.org/dataset/reach-libya-national-schools-assessment-2012	13.02.2017	100%	26%
Lithuania	-	Address	Data request	Ministry of Education and Science of the Republic of Lithuania	06.03.2017	98%	2%
Malawi	-	Coordinates	Data request	Ministry of Education; Malawi	21.03.2017	90%	0%
Marshall Islands	-	Address	Download	Education Digest 2013-2014; Ministry of Education; Republic of the Marshall Islands; Retrieved from: http://prism.spc.int/reports/education	25.11.2016	88%	37%

Table A.3: GPS coordinates data sources

Country	State/Province	Data type	Collection method	Data source	Date obtained	Completeness	Shared coordinates
Mexico	-	Coordinates	Download	Sistema Nacional de Informacion de Escuelas; Secretaria de Educacion Publica; Mexico; Retrieved from: http://www.snie.sep.gob.mx/SNIESC/	02.10.2017	100%	24%
Mongolia	-	Coordinates	Data request	National Statistical Office of Mongolia	12.01.2017	80%	0%
Mozambique	-	Coordinates	Data request	Ministerio da Educacao e Desenvolvimento Humano; Republica da Mocambique	08.05.2017	95%	2%
Netherlands	-	Address	Download	Dienst Uitvoering Onderwijs; Ministerie van OCW; Retrieved from: https://www.duo.nl/open_onderwijsdata/databestanden/po/	06.02.2017	100%	< 1%
New Zealand	-	Coordinates	Download	Ministry of Education; New Zealand Government; Retrieved from: https://www.educationcounts.govt.nz/data-services/directories/list-of-nz-schools	02.10.2017	99%	0%
Norway	-	Address	Download	Pedlex; Retrieved from: http://skoleadresser.no/	22.08.2018	96%	< 1%
Pakistan	Punjab	Coordinates	Download	School Education Department; Government of Punjab; Retrieved from: http://schoolportal.punjab.gov.pk/census/	06.10.2017	94%	5%
Pakistan	Sindh	Coordinates	Download	Education and Literacy Department; Government of Sindh; Retrieved from: http://www.rsu-sindh.gov.pk/downloads/schoolSearch.php	05.02.2018	74%	5%
Paraguay	-	Coordinates	Download	Ministerio de Educacion y Ciencias; Paraguay; Retrieved from: http://datos.mec.gov.py/data	24.01.2017	94%	< 1%
Peru	-	Coordinates	Download	Ministerio de Educacion; Peru; Retrieved from: http://sigmed.minedu.gob.pe/mapaeducativo/Ministerio de Educacion; Peru; Retrieved from: http://sigmed.minedu.gob.pe/mapaeducativo/	27.09.2017	99%	< 1%
Philippines	-	Coordinates	Download	Department of Education; Philippines; Retrieved from: https://deped.carto.com/tables/deped_school_location_with_enrolment_2014_2015/public	23.01.2018	87%	2%
Poland	-	Address	Download	Centrum Informatyczne Edukacji; Poland; Retrieved from: https://cie.men.gov.pl/sio-strona-glowna/podstawowe-informacje-dotyczce-wykazu-szko-i-placowek-owiatowych/wykaz-wg-typow/	29.01.2018	96%	5%
Puerto Rico	-	Coordinates	Download	U.S. Department of Education; National Center for Education Statistics; Common Core of Data (CCD); Public Elementary/Secondary School Universe Survey CCD School Data 2014-15; Retrieved from: http://nces.ed.gov/ccd/	10.07.2017	100%	10%
Saint Kitts and Nevis	-	Address	Download	Statistical Digest 2013-2014; St. Kitts and Nevis Ministry of Education; Retrieved from: http://www.moeskn.org/	08.12.2016	100%	0%
Saint Lucia	-	Address	Download	Education Statistical Digest 2015; Ministry of Education, Human Resource Development and Labour; Government of St. Lucia; Retrieved from: http://education.govt.lc/publications/	08.12.2016	100%	19%
Saint Vincent and the Grenadines	-	Address	Download	Education Statistical Digest of St. Vincent & the Grenadines 2014-2015; Retrieved from: http://www.education.gov.vc/education/	08.12.2016	96%	3%
Samoa	-	Address	Download	Education Statistical Digest 2015; Ministry of Education, Sports, and Culture; Samoa; Retrieved from: http://prism.spc.int/reports/education	25.11.2016	83%	13%
South Africa	-	Coordinates	Download	Education Management Information System; National Department of Basic Education; South Africa; Retrieved from: http://www.education.gov.za/Programmes/EMIS.aspx	02.11.2016	99%	1%
South Sudan	-	Coordinates	Download	Education Management Information System; South Sudan; Retrieved from: http://www.southsudanemis.org/data	04.11.2016	81%	41%
Tanzania	-	Coordinates	Download	President's Office; Regional Administration and Local Government; The United Republic of Tanzania; Retrieved from: http://opendata.go.tz/dataset/	02.02.2018	72%	22%
Uganda	-	Coordinates	Download	Schooling Uganda; Retrieved from: https://schooling.ug/	20.10.2017	74%	0%
UK	England	Address	Download	Department for Education; England; Retrieved from: https://data.gov.uk/dataset/	09.07.2017	100%	1%
UK	Northern Ireland	Address	Download	Department for Education; Northern Ireland; Retrieved from: http://apps.education-ni.gov.uk/appinstitutes/default.aspx	07.02.2017	100%	0%
UK	Scotland	Address	Download	Scottish Government; Retrieved from: http://www.gov.scot/Topics/Statistics/Browse/School-Education/	07.02.2017	100%	2%
UK	Wales	Address	Download	Statistics Wales; Welsh Government; Retrieved from: http://gov.wales/statistics-and-research/address-list-of-schools/?lang=en	07.02.2017	100%	3%

Table A.3: GPS coordinates data sources

Country	State/Province	Data type	Collection method	Data source	Date obtained	Completeness	Shared coordinates
Uruguay	-	Coordinates	Download	Administracion Nacional de Educacion Publica; Uruguay; Retrieved from: http://sig.anep.edu.uy/siganep	02.04.2018	100%	8%
US	-	Coordinates	Download	U.S. Department of Education; National Center for Education Statistics; Common Core of Data (CCD); Public Elementary/Secondary School Universe Survey CCD School Data 2014-15; Retrieved from: http://nces.ed.gov/ccd/	10.07.2017	100%	1%
Zambia	-	Coordinates	Data request	Ministry of Education; Zambia	14.06.2016	77%	3%

This table lists the data sources for the GPS coordinates of public primary schools for all countries where such data could be obtained. The last two columns indicate the share of schools for which coordinates were obtained and the share of schools with coordinates that have identical coordinates as one or more other schools.

[44] Disclaimer: Results for Hungary have been created with the use of WTorsten_cimlista_altisk_tan_ped_2015-16.xlsx Datafile prepared upon individual request by the Hungarian Central Statistical Office (www.ksh.hu). The calculations and the conclusion are the sole intellectual products of the author Torsten Figueiredo Walter.

Table A.4: Data on other school inputs

Country	Source	Year
Benin	PASEC	2014
Burkina Faso	PASEC	2014
Burundi	PASEC	2014
Cambodia	Annual School Census	2014
Cameroon	PASEC	2014
Congo	PASEC	2014
Cote d'Ivoire	PASEC	2014
Ethiopia	Annual School Census	2016
Guinea-Bissau	PASEC	2014
India	Annual School Census	2015
Kenya	UWEZO	2014
Liberia	Annual School Census	2015
Mozambique	Annual School Census	2016
Niger	PASEC	2014
Pakistan (Punjab)	Annual School Census	2014
Senegal	PASEC	2014
South Sudan	Annual School Census	2015
Tanzania	UWEZO	2013
Tchad	PASEC	2014
Togo	PASEC	2014
Uganda	UWEZO	2014
Zambia	Annual School Census	2015

This table lists the data sources for the analysis of the relationship between pupil-classroom ratios and pupil-toilet ratios, and school-level PTRs across schools within countries.

Table A.5: DHS data on adult education

Country	Year

Table A.5: DHS data on adult education

Country	Year
Cambodia	2014
Dominican Republic	2013
Kenya	2014
Liberia	2013
Malawi	2015
Mozambique	2011
Pakistan	2017
Philippines	2017
South Africa	2016
Tanzania	2015
Uganda	2016
Zambia	2013

This table lists the DHS waves merged to school census data for the analysis of the relationship between adult education and school-level PTRs across space within countries.

Table A.6: Data on pupils' mothers' literacy

Country	Source	Year
Benin	PASEC	2014
Burkina Faso	PASEC	2014
Burundi	PASEC	2014
Cameroon	PASEC	2014
Congo	PASEC	2014
Cote d'Ivoire	PASEC	2014
Ethiopia	Young Lives	2012-13
Guinea-Bissau	PASEC	2014
India	ASER	2014
Kenya	UWEZO	2014
Niger	PASEC	2014
Pakistan	ASER Pakistan	2015
Senegal	PASEC	2014
Tanzania	UWEZO	2013
Tchad	PASEC	2014
Togo	PASEC	2014
Uganda	UWEZO	2014

This table lists the data sources for the analysis of the relationship between pupils' mothers' literacy and school-level PTRs across schools within countries.

Table A.7: Data on average class size

Country	Source	Year
Kenya	UWEZO	2014
Mozambique	Annual School Census	2016
Pakistan	Annual School Census Punjab	2014
Tanzania	UWEZO	2013
Uganda	UWEZO	2014
Zambia	Annual School Census	2015

This table lists the data sources for the analysis of the relationship between average class size and school-level PTRs across schools within countries.

Table A.8: National primary school exam scores

Country	Examination	Grade	Subject(s)	Year
Brazil	ANA	3	Maths	2016
Chile	SIMCE	6	Maths	2015
Dominican Republic	Pruebas nacionales	8	All	2016
India (Madhya Pradesh)	District Examination	5	All	2009
Mexico	PLANEA BASICA	6	Maths	2015
Sweden	National exams	6	Maths	2015
Tanzania	PSLE	7	All	2016
UK (England)	Key Stage 2	6	Maths	2016
US (New York)	NY state test	5	Maths	2015
Zambia	PSLE	7	All	2014

This table lists the national examinations used in each of the 10 simulation countries.