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Simulating the impact of a raise in education salaries on economic growth in Peru

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A B S T R A C T

A simulation shows that increasing teacher salaries is likely to be (very) profitable for Peru. The required investments have in the long run a substantial return in economic growth as higher salaries would lead to higher teacher cognitive skills, which in turn impact student achievement. We suggest that international development banks should develop products for education finance with a long period (60 years or more) before repayments must be made.

1. Introduction

We want to explore to what extent a substantial increase in teacher salaries in Peru is economically beneficial in the long run. This angle may come as a surprise as teacher salaries, relative to the salaries of other workers with a similar background have hardly been discussed in terms of the potential economic benefits. However, recent studies have clearly indicated a potential train of thought, where higher teacher salaries might induce more talented youngsters towards the teaching profession. In turn, such teachers might induce students to learn better so that in the end become better trained workers that produce more and better. It is this train of thought we shall pursue here for Peru based on evidence world-wide.

The backdrop of this work is the central role of education in the development agenda. Back in 1948, the United Nations' Universal Declaration of Human Rights emphasized that: "Everyone has the right to education. Education shall be free, at least in the elementary and fundamental stages. Elementary education shall be compulsory. Technical and professional education shall be made generally available and higher education shall be equally accessible to all based on merit." (United Nations, 1948, Article 26, para. 1). The call for universal primary education came at around the same time as the "discovery" of human capital, through Denison's assessment of the sources of economic growth (Denison, 1962). The accumulation of physical capital could only explain about one third of economic growth in the

US while traditional economic models relied on physical capital as the only source of productivity per worker. Denison suggested that the “unexplained” part of economic growth is the result of more and better education which - through research and development - leads to new knowledge and innovation, thus higher levels of productivity. Human capital theory was founded. The economic success in Asian economies such as Korea and Singapore was presumably achieved through implementing the notions of this theory; allowing them to catch-up during the second half of the 20th century and transit towards the developed world (Ashton et al., 2002; Marginson, 2011).

Gradually, it also became evident that education is not just about being in school but also about learning: quality really matters. The quality of education is later reflected in the productivity of the worker (see for example: Hanushek, 2005).

In most of Latin America, basic education is not even compulsory and the public education systems does not provide enough places for all youngsters to participate (Semana, 2017). At the same time, public schools are of poor quality. Pupils coming from households in the upper segments of income distribution are often enrolled in private schools where price determines the educational quality received. Inequality of opportunity is a major source of civic tension. Such is the case in Peru. In the Project International Student Assessment PISA, measuring the achievements of students at age 15/16 across countries along the same scale, the performance of Peruvian students in the PISA test has remained stagnant on a level of less than 400 (in year 2018), compared to a level of 500 for the average of the more than 70 countries that participated in the project. This poor performance of the educational system in Peru might be also hampering the country’s economic growth, which is already facing an economic slowdown since 2015, after almost two decades of uninterrupted growth.

We aim to bring a fresh perspective for educational reforms in the developing world by shifting the focus to improving teachers’ cognitive skills as a means to raise the level of human capital and its contribution to economic growth.

We ask the question: what would it take in terms of teacher salaries to raise student attainment to 500 PISA points (the average of the 79 countries that participated in PISA) in Peru, and what might be the benefits in terms of economic growth?

In section 2 we discuss where we stand in our knowledge on educational quality and economic growth. What is the impact of student performance at age 15/16 on economic growth? What is the relation between teacher competencies and student performance? As the third line we consider what we know about the empirical relation between teacher salaries on teacher competences.

In section 3 we present the data used for the econometric analyses and indicate how we simulate the effects of a raise in teacher salaries for economic growth in Peru. The empirical results of the regression and the simulation are presented in section 4. Section 5 summarizes the simulation results in a cost-benefit analysis that strongly supports the idea of an educational reform in Peru. The last section 6 concludes and provides policy recommendations asking attention for mechanisms for developing countries to finance profitable education investments. The returns to the investment take at least 40 years to accrue. The world needs finance vehicles to invest in the long-run future.

2. Education, teacher salaries and growth

2.1. Education increases productivity

Education is an investment unalienable from the individual and leads generally to additional income. Differences in investment between people then also explain income differences (Mincer, 1974) and for example (Björklund & Kjellström, 2002) (Heckman et al., 2006).

Education then also promotes growth through amongst others innovation (Lucas, 1988; Romer, 1990) (Benhabib & Spiegel, 2005). For Latin America – our focus - evidence on the relation between income and education is found in (Patrinos & Psacharopoulos, 2010).

2.2. Quality matters and teachers make the major difference

Differences in income between countries and between individuals can be attributed to differences in the quality of education received as became clear when quality measures like international standardized tests such as PISA and PIAAC (Project International Assessment of Adult Competencies) became available (Ritzen, 2017). Analysis shows that learning (i.e. providing quality education) and economic growth are closely related, making the effect of the nominal years of schooling per se less relevant (Hanushek & Woessmann, 2012). Competencies are important at the individual level because they have a direct impact on the earnings of workers that can even outweigh the effect of nominal years of schooling (Hanushek et al., 2015). Schooling is not the same as learning and using the prior would turn to be an imprecise proxy for assessing educational systems and its' relation to economic growth (Filmer et al., 2020).

Hattie presented a synthesis of over 800 meta-analyses on student achievement to identify the impact of 138 influences to learning outcome covering more than 80 million students (Hattie, 2009). The competences of the teacher emerge from this analysis as by far the most important "input" in the education system to reach quality learning (Falchikov & Boud, 1989; Falchikov & Goldfinch, 2000; Hattie, 2011, 2015; Kuncel et al., 2005; Mabe & West, 1982; Ross, 1998).

Further evidence on the importance of competencies of teachers for quality education– came from a empirical study on student achievement and the competencies of teachers (Hanushek et al., 2019) for 31 countries. An improvement in teacher cognitive skills of one standard deviation can lead to a .2 standard deviation improvement in student math and reading performance. This statistical coefficient is highly significant. Similar results are found by Meroni in 2015 (Meroni et al., 2015).

2.3. Better salaries draw better teachers into the profession (Hanushek, 2020)

Previous research has found a significant relationship between offering more competitive salaries in public schools and a higher attraction of experienced teachers to the profession (Hendricks, 2015). In another study here is also empirical evidence that countries with higher average salaries for experienced teachers have higher scores in national student achievement tests, even though there is not found a significant relationship between starting salaries and student achievement directly (Akiba et al., 2012).

Hanushek et al. (2019) observed from PIAAC and salary data that country variations in teacher cognitive skills are significantly related to salary premiums for teachers. Controlling for the wage level of college graduates, they find that one standard deviation higher relative teacher salaries is associated with higher teacher skills in numeracy (literacy) of about 40 percent (30 percent) of an international standard deviation.

2.4. Simulation of the policy effect measures

The effect of policy measures on outcomes, using the evidence from cross sectional or panel data is prevalent throughout social sciences. An example in human capital policy is in Collin and Weil (Collin & Weil, 2018) developed by the World Bank. They examine the dynamic responses of income and poverty to increased investment in the human capital of new cohorts of workers, as well as on fertility and the follow-on effects of lower fertility on income.

3. Data

Four (mostly) publicly available sources are used for this paper:

i) The results of the PISA tests conducted 2009, 2012, 2014, 2015 and 2018 for a set of 35 countries,

ii) The three rounds of the PIAAC project of 2012, 2015, 2018, for the same set of countries,

iii) The World Bank database of economic data for the period 2000-2019 on GPD per capita, and

iv) Administrative data from Peruvian public institutions to complement the salary data available for 29 OECD countries.

The Program for International Student Assessment (PISA) provides relevant data on student attainment regarding their skills in numeracy, literacy, and science. The eighth round of the program was completed in 2018 and measured the skills of 15/16-years-olds in 79 countries that have joined the PISA project. PISA is repeated every three years.

The second data source is the Program for the International Assessment of Adult Competencies (PIAAC) using similar measures as PISA for adults aged 16 – 65 in more than 40 countries around the world focusing on their numeracy and literacy skills, as well as their ability to function in technology-rich environments. The first cycle of PIAAC was completed by 2018 and included the occupation of the tested adults. This allows for a comparison of the cognitive skills of teachers across the different countries and within a country between teachers and other groups of professionals. PISA and PIAAC are standardized international tests. As a result, both are well useable for assessing the relation between teacher competencies and student achievement in the countries that participated (Hämäläinen et al., 2019; Hanushek et al., 2019; Meroni et al., 2015).

The third source is the World Bank Open Data portal for data on economic performance (GDP, GDP growth, GDP per capita), on health (anemia incidence) and educational systems (student – teacher ratio, teacher statutory salaries). We have used these data for the years 2000-2019.

PISA tests only provide complete observations for 35 countries for the period 2009-2018 (see Appendix 1 for the countries in the sample). Previous studies used smaller samples.

Teacher competencies (PIAAC) are also available for these 35 countries (adding Hungary, Kazakhstan, Mexico, and Peru to the sample analyzed by (Hanushek et al., 2019).

The full description of the dataset is provided in Appendix 1. Note that the data on teachers' competencies (numeracy and literacy) are one-time observations[1]. Teacher cognitive skills are calculated by using the median in the country, as it is a more reliable measure in smaller samples like those of the PIAAC test.

Appendix 2 compiles the data by occupation which provides a relatively modest number of observations per country. At the same time previous studies have found consistency between these figures and those from a national teacher census (Hanushek et al., 2019). The PISA score for each year is the national weighted average for either numeracy or literacy skills obtained from each of the Public Use Files of the project.

There is a disconnect in the time spans for both PIAAC (2011 – 2018) and PISA (2009 – 2018). However, teacher cognitive skills are stable across the mid-term and change only slowly. The same holds true for PISA scores.

We use nominal values to facilitate the reader a straightforward understanding on the magnitude of the relationship between teacher cognitive skills and student achievement, especially when developing the Peruvian case and deviate from

[1] The USA participated more than once; this was introduced in the data base as a separate observation.

Hanushek's z-standardization process as this is less intuitive.

In Appendix 3 we present an impression of the relation of the median teacher cognitive skills for each country and student average competencies using our data. Figure 3.1 and Figure 3.2 show the positive correlation. Peru is lagging compared to the rest of our sample, although it has a relatively close position to the fitted line. The proximity to the fitted lines is reasonably close, except for Kazakhstan that is not achieving similar results in their student literacy skills as other countries with similar teacher competencies. Finland and Japan present the highest cognitive skill levels for teachers. However, they are outperformed by Singapore and Korea in terms of student achievement.

In Appendix 4 we provide the correlation matrix of the variables in the dataset. A high correlation (>|0.8|) is observed between the starting teacher salaries in primary, lower secondary and upper secondary. This suggests it is better to use a global average for the starting statutory salaries per country (*avg_tsalary_0*) instead of the 3 separate variables by education level. A similar situation occurs with the pupil-teacher ratio in lower and upper secondary school, therefore a new average variable named *pt_ratio_sec* was created.

4. Our Model for Estimation and Simulation

4.1. Teacher competencies and student achievement

We estimate a model where student cognitive skills are related to teacher cognitive skills:

$$A_{cs} = \alpha_0 + \alpha_1 T_{cs} + \mu \qquad (1)$$

A_{cs} denotes the average cognitive skills of students in country *c* for a specific subject *s* (either numeracy or literacy), while T_{cs} denotes the teacher median cognitive skills in country *c* for specific subject *s* and μ is the disturbance term, with PISA and PIAAC cross-section data for 35 countries using Ordinary Least Square. This method is not efficient to capture fixed-effects or analyze trends over a period. Also, we realize that the model uses aggregate country-level median and average teacher and student cognitive skills. Using country averages can lead to biased estimators due to sorting of students and teachers (i.e. it cannot be determined who taught who). The error term μ in Eq. 1 could contain both idiosyncratic differences like low household demand for education (i.e. parents not enrolling kids into school) and unmeasured country differences that are subject-specific and are difficult to capture in a cross-sectional setting.

We realize that there are other factors that could explain student achievement, in addition to teacher cognitive skills. In fact, the distribution of the correlations observed in the Figures 3.1 and 3.2 in the Appendix 3 suggests that there are systems that get a higher return on student learning with lower levels of teacher cognitive skills. This might be the product of other variables influencing the outcome. To reflect on some of these differences across countries and to validate the robustness of the estimator, we conduct robustness checks addressing four variables: teacher salaries, GDP, anemia incidence (Castro & Viana, 2019; Petranovic et al., 2008), and lastly, the pupil-teacher ratios in each country.

4.2. Salaries and competencies

We use for our estimations the remunerations at an average school level (including primary, lower, and upper secondary) instead of just high-school salaries as in previous studies. As it could be reasonably argued, student cognitive development starts in the early childhood and the results of PISA test, usually taken by 15-years old students, reflect on a long-term learning journey that starts in the most basic form of education. Consequently, paying attention to just the salary levels in high schools would ignore the importance of having qualified teachers during the earlier stages. For this, the econometric analysis of salaries and teacher cognitive skills has been structured as follows (model 2):

$$(\ln)T_{cs} = \beta_0 + \beta_1(\ln)S_c + \mu \quad (2)$$

Here T_c denotes the average teacher cognitive skills in country *c* for skill *s*, based on starting statutory salaries in the respective country S*c* and other factors that could be contained in the error term μ. Eq. (2) is estimated with the data mentioned in section 3. Since salaries and the scores on cognitive skills in the sample have a skewed distribution (see Figures 3.3 and 3.4 in Appendix 3), we use a logarithmic transformations to approximate both variables to a normal distribution. The use of nominal statutory salaries at the international level has drawbacks, as the attraction to the teaching profession is presumably better represented by the salaries of teachers relative to those of other professions with the same level of education achieved. Therefore contemplates (Hanushek et al., 2019) uses a national premium variable for teachers with respect to average graduate salaries to estimate the relation between salaries and teacher competencies. Unfortunately, this not possible as such data are missing information in OECD Public Use Files. Controlling for country fixed effects is also not possible as panel data is not available.

A second shortcoming of this approach is the linearity assumption. We find a single estimate for the international market, which includes countries at different stages of development. We have not tested for non-linearities or multiplicative effects, for example for the possibility that in developing countries the sensitivity for teacher salaries is different.

4.3. Student performance and growth

In the third model, the relationship between increased student achievement and long-term GDP per capita is explored. For this, this research follows the basic notions of Hanushek et al. 2019, by regressing the average cognitive skills during a 20-year period into the average GDP per capita. Different to the two previous models, this stage now uses the average of student achievement for both subjects (i.e. average of numeracy and literacy combined) to determine whether they have an influence in the long-term GDP per capita since student achievement and economic growth are related through the accumulation of Human Capital, which is not necessarily related to one skill or the other but more likely the general cognitive capacity in the work force.

As this approximation benefits from a wide timespan, the dependent variable *gdp_pc1* comprises the average GDP per capita of the 36 countries during the period 2000 – 2019 to find a relationship on the production of countries and the available human capital with student achievement. The GDP per capita is an interesting indicator to use for this regression because, contrary to nominal total GDP, it considers production in relation to population and this can reflect better on the productive capacities of the workforce. Regarding the independent variable *avg_cognitive*, it comprises the average national PISA scores from each country for the tests that took place between 2000 to 2018.

As in OLS model 2, logarithmic transformations are used for a better fitting of the data and understanding the relationship between a potential increment in student cognitive skills and the long-term GDP growth. Model 3 is defined as follows:

$$(\ln)G_c = \theta_0 + \theta_1(\ln)A_c + \mu \quad (3)$$

Here G represents the average GDP per capita in country c for the period 2000 – 2019 and A represents the average cognitive skills of students in such country for all the rounds of PISA test during the same period. The error term μ would then contain unmeasured explanatory variables that drive GDP per capita growth. These could be country-specific (i.e. availability of natural resources) or generalized (i.e. global crisis events).

4.4. Prospective analysis / Simulation

We use the models 1-3 for a simulation of a substantial increase of teacher salaries on economic growth on the long run through the following string: salaries increase the attractiveness of the teaching profession for more talented students (model 2). More competent teachers lead to better education outcomes (model 1), and higher achievements of students leads on the long run to more productive workers and more economic growth (model 3). This exercise is in line with that of Collin and Weil (Collin & Weil, 2018)

The increase in teacher cognitive skills X required to achieve a PISA score for pupils of 500 in subject *s* from the present level of A_{sp} can be computed with Eq. (1) to be:

$$X = (500 - A_{sp}) / \alpha_1 \qquad (4)$$

So that the "required" level of teacher competences to reach a student achievement of 500 becomes: $T_{cs} + X$, where x is the relative increase ($x=X/ T_{cs}$) . For the computation of the "uncertainty" envelope we take one standard deviation around the average coefficient.

This increment is achieved by a teacher starting salary sY using Eq. (2) of:

$$\ln (1+s) = \ln(1+x) / \beta_1 \qquad (5)$$

We hypothesize a 5-year time-lag before more talented teachers appear in schools after the raise in salaries (the duration of a bachelor's degree) and subsequently 11 years before the first cohort of students will be able to achieve the 500 PISA threshold, then another 5 before these better trained students appear on the labor market (5 years) and lastly 20 years before we will see the effect of increased capacities of workers on productivity and higher GDP per capita. In other words, Peru would be funding the reform for around 41 years before seeing the full potential of the economic returns created by enhanced productivity and human capital. Adding up the in terms of higher salaries over the period since the start of the initiative over the long run presents us an indication of the investment costs.

Also, for the coefficient β_1 we use one standard deviation to describe an envelope. The combination of the standard deviations of the coefficients α_1 and β_1 presents us with a total of 4 envelopes for each of the two student achievement categories (literacy and numeracy).

On the benefit side we have the additional GDP calculated from Eq. (3), starting after 41 years, and lasting indefinitely on a level of student achievement of 500.

5. Findings

In Tables 1a and 1b, the results of model 1 are presented. These can be considered to be re-analyses of (Hanushek et al., 2019) analysis with more PISA rounds. The estimated coefficient become slightly smaller the more PISA rounds are included in the analysis, perhaps because of measurement error.

Table 1a: Student achievement and teachers' literacy

Variable	original[/1]	Plus 1	Plus 2
tlit	1.623***	1.590***	1.547***
Constant	16.459	25.831	37.978
N	36	36	36
r2	0.810	0.816	0.794
r2_a	0.804	0.810	0.788

1/ PISA 2009 and 2012 literacy average, Plus 1: original + 2015, Plus 2: original + 2015 and 2018
Source: own elaboration. Significance levels: *p < 0.10, **p < 0.05, ***p < 0.01.

Table 1b: Students' and teachers' numeracy

Variable	original [/1]	Plus 1	Plus 2
Tnum	1.593***	1.540***	1.492***
Constant	30.816	44.891	59.055
N	36	36	36
r2	0.702	0.696	0.687
r2_a	0.693	0.687	0.678

1/ PISA 2009 and 2012 numeracy average, Plus 1: original + 2015, Plus 2: original + 2015 and 2018 Source: own elaboration. Significance levels: *p < 0.10, **p < 0.05, ***p < 0.01.

These results are stable, also when adding control variables, as is shown in Appendix 5, Tables 5.1 and 5.2.

5.2. Starting salaries and teacher cognitive skills

Table 2 present the OLS regression of teacher salaries and teacher competencies (model 2), using the average statutory salaries of 30 OECD countries in the sample during the period 2010 – 2018 that includes teachers in primary, lower secondary and upper secondary. We have complemented this information with the average teacher salaries in Peru.

Table 2: Average starting salaries and teacher cognitive skills

Variable	Numeracy	Literacy
log_avg_tsalary_0	0.074*	0.083**
r2_a	0.148	0.223
Std err	.0402	.0375

Data Sources: World Bank, MINEDU, OECD, PIAAC (2012, 2015, 2018). Own elaboration. Significance levels are as follow: *p < 0.10, **p < 0.05, ***p < 0.01.

As shown, 1% increase in teacher salaries will lead, on average, to approximately 1/10 of a percent increase in their numeracy and literacy skills. Note that we have used nominal salaries instead of national relative salaries. This could explain the low adjusted R2 of the model.

Figures 6.1 and 6.2 in Appendix 6 show the data on the salaries and on teacher competences around the fitted line. The logarithmic nature of the relation (with a coefficient well below zero) implies that developed countries might find it more costly to increase student achievement by exclusively paying for attracting better teaching talent. Student achievement by a salary reform would then be more suitable for those countries in lower states of student achievement.

Note that the estimator reflects the relationship of salaries *at the international level* and national teacher cognitive skills. Ideally, we would want to consider national teacher salaries in relation to other occupations with a similar educational background, if these were available (which is not the case).

5.3. Improved student achievement and economic growth

As can be seen in Table 3, a 1% increase in student cognitive skills leads, on average, to a 6% increase in the GDP per capita at a 1% significance level. This estimate is arrived at is made by using time overlapping averages of student achievement and GDP per capita, which does not take into consideration the time between capital is built up through higher student proficiency levels and the time this progress is transformed into actual skills triggering higher productivity. However, history has shown that those periods can be very relative depending on the case. Korea and Singapore, for example, achieved a tremendous transformation of their local skills during a one generation period that led them towards the "East Asian Miracle" of the 90's. Hitherto, earlier industrialized countries had taken several generations to transit that path (Ashton et al., 2002).

A second specification using a wider time frame of GDP per capita provides a higher adjusted R2 and an almost identical impact of student performance on GDP per capita. The regression of the log average cognitive skills of students on long term GDP per capita develops interesting and consistent results. As it can be seen in Figure 7, the average GDP per capita in the countries of the sample have important differences from period to period but their relationship with cognitive skills remains surprisingly constant. There are two possible explanations to this: i) there has been a proportional shift in the average GDP per capita of all the countries in the sample during both time periods (unlikely) or ii) the contribution of human capital to GDP per capita is somehow stable across countries while the rest is endogenous growth driven by other explanatory factors.

Table 3: Student achievement and economic growth

Variable	(1)	(2)
Avg. student achievement	6.469***	6.474***
r2_a	0.516	0.583
Std. error	.576	.680

Data Sources: World Bank, OECD, PISA (2000, 2003, 2006, 2009, 2012, 2015, 2018). Own elaboration. . Significance levels: *p < 0.10, **p < 0.05, ***p < 0.01.

Like for wages and teacher skills, the effect of increased student skills on economic growth is greater in earlier stages of development as shown in Appendix 7. This is true both for the 2000-2019 interval (left) and the 1970-2019 interval (right). An interesting insight of this graph is that Peru and Mexico, largely lagging in student and teacher performance, are performing slightly above the curve when analyzing the GDP per capita levels. This could be explained by the economic models of countries that rely heavily in the production and exploitation of natural resources, rather than the development of human capital. In contrast, Singapore, and Korea - with their economic models based on knowledge and innovation but scarce natural resources - are situated under the curve but largely ahead the Latin American economies in terms of GDP per capita.

5.4. The costs of reaching PISA 500 score by raising teacher salaries

We simulate the potential mechanisms to raise the proficiency in numeracy and literacy skills of Peruvian youngsters from the present (2018) level of around 400 to 500. This is a huge leap as Peru's improvement across the last four editions of PISA (between 2006 and 2018) has been roughly 30 points. At the current pace, it could take at least 3 generations to achieve the desired (namely the average of the developed world) level of proficiency. We calculate here the impact of increased teacher salaries to reach the desired level of teacher proficiency, needed to reach the student achievement level of 500 as outlined in section 4.4.

Peru has a potential gap in teacher cognitive skills of around 60 and 74 points for numeracy and between 58 and 71 for literacy when taking an envelope of one standard deviation around the average coefficient.

The increase in salaries needed to achieve these higher teacher competencies is calculated as in section 4. Results are shown in Table 4 below. We choose for the alternative of the higher coefficients for numeracy for a calculation of the costs.

Table 4: Required raise of teacher salaries

		Numeracy		Literacy	
		Higher α1	Lower α1	Higher α1	Lower α1
numeracy	Lower β1	816%	981%		
	Higher β1	241%	290%		
literacy	Lower β1			571%	691%
	Higher β1			216%	261%

Peru would need to increase the teacher salaries by 241%. This would mean, in nominal terms, an increase of roughly USD 25,200 to take their starting annual salary level to approximately USD 35,600; this is relatively close to the median salary in the sample of USD 29,295. The model considers an implementation period of 41 years before the realization of the full returns on economic growth (i.e. GDP per capita). Until then, considering there are roughly 400,000 teachers in the public schools of Peru, the government would have invested USD 14.2 billion annually (6.22% of the GDP) up to a total amount of USD 584 billion.

At first, this could seem like an extremely high number, especially considering that OECD countries spend roughly 3.4% of their GDP in basic schooling (OECD, 2016). Nonetheless, the future returns of the expected increase on student attainment and later enhanced human capital are substantially larger. This is, for every percentage point increase in student cognitive skills, there is a 6.47% growth in the average long-term GDP per capita. In this way, the expected 25% surge in student cognitive skills (from 400 to 500 PISA points) would lead to an astonishing 161.75% increment of GDP per capita over the long run. In nominal terms, this would mean to take the current USD 6,977 GDP per capita to USD 18,262 or roughly adding USD 584.4 billion to the annual Gross Domestic Product.

After the initial 40 years, the country would keep spending annually around US$ 15 – 17 billion in teacher salaries; considering inflation and eventual marginal raises to reward those experienced educators. Raises are crucial for the sustainability of the intervention to avoid a new cycle of devaluation of the teaching career due to cuts in the real value of salaries. Nonetheless, Peru would at the same time keep producing additional US$ 584.4 billion GDP, taking the annual costs of increased teacher salaries down to only 1.9% of the total GDP. At this stage, teacher salaries could be easily funded by the increased tax revenues of a larger economy with also higher levels of formal activity that, today, is no higher than 30%. The increased revenue coming from taxes in a larger economy would make feasible to also cover any interests associated to long-term debt that Peru would very probably need to take for financing the heavy initial investments.

In addition, the actual salaries represent theoretically a sunk cost (i.e., it is paid today already and will be paid in the future as well). Under this approach, the returns over investment are even larger. The total additional spending in education for the whole period would be US$ 413.2 billion and the expected increase in GDP per capita would remain, making the payback period shorter. Undoubtedly, it seems that, for Peru, investing to improve education by raising teacher competencies will result not only in addressing an urgent social need but, in fact, a tremendously good business that is sustainable over the decades to come.

6. Summary and policy recommendations

We first analyze econometrically for a sample of 35 countries the impact of teacher cognitive skills on student achievement. Highly significant (1%) estimates were obtained even when controlling for other important traits that supposedly explain early cognitive development or student achievement. We find that student achievement increases by 1.5 points for every point increase in teacher's cognitive skills in numeracy and literacy (around a world average of 500). These empirical results confirm earlier findings that teachers matter more than anything else, defying some common priorities in education policy such as class sizes or hours of schooling (Hattie, 2015).

Subsequently we hypothesize that teacher competencies are related to salaries: higher salaries might attract more talented youngsters to the profession. Indeed, we find that increases in starting annual salaries do have a significant impact on teacher cognitive skills in line with earlier findings (Hanushek et al., 2019), even though it requires substantial salary steps to increase competencies of teachers: As shown, 1% increase in teacher salaries will lead, on average, to approximately 1/10 of a percent increase in their numeracy and literacy skills. The third relationship explored through econometrics is the relationship of student attainment and economic growth. A 1% increase in student cognitive skills leads, on average, to a 6% increase in the GDP per capita at a 1% significance level. We find that every percentage point increase in the average student achievement boosts by 6.5% the long-term GDP per capita.

These findings were used for a simulation of a substantial increase in teacher salaries in Peru. First, we calculate the salary increase needed to reach a level of average student achievement to 500 PISA points and calculate the costs involved. Peru would need to increase the teacher salaries by 241% in the scenario where the 500 level is achieved for numeracy and the coefficients are applied in the scenario with the one standard deviation upward level, or an increase to a starting annual salary level to approximately USD 35,600, with annual investments of USD 14.2 billion annually (6.22% of the GDP), totaling over a 41-year gestation period up to USD 580 billion.

At the benefit side the envisioned surge in student cognitive skills (from 400 to 500 PISA points) would lead to an astonishing around 160 % increment of GDP per capita over the long run or roughly adding annually USD 580 billion to the Gross Domestic Product, so that repayment taken out for the loan could take place in one single year.

Our simulation clearly indicates that there are substantial long-term economic returns to higher investments in education in Peru through raising teacher salaries as a means to attract more talented teachers to the job and train them better.

The Peruvian case is a clear example of the potential negative consequences that not paying enough attention to educators can generate (Díaz & Saavedra Chanduví, 2000). The policy approach to education should have focused on *quality* and not just on quantity or access. Access only delivers high economic returns when combined with quality. Universal quality education in Peru should be achieved by combining both.

How can the funds be raised for profitable investments in education as shown in our simulation in developing countries like Peru? Taxation or shifts in Government expenditure offer insufficient possibilities. At the same time there is no international capital market to borrow from. International development institutions like the World Bank or regional development banks, such as the IADB have it present no financial products with the time horizon of some 40 years, required here.

Our conclusion justifies the development of new financial products for International Development Banks who can deal with this, of course under conditions of sound macro-macro-economic and educational policy.

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Appendix 1 - Database codebook

#	Variable	Description	Source
1	country	Each of the 35 countries + additional USA observation	-
2	code	Country Code	-
3	tnum	Median teacher's numeracy skills according to PIAAC	OECD
4	Tlit	Median teacher's literacy skills according to PIAAC	OECD
5	slit2000	Average student literacy PISA 2000	OECD
6	slit2003	Average student literacy PISA 2003	OECD
7	slit2006	Average student literacy PISA 2006	OECD
8	slit2009	Average student literacy PISA 2009	OECD
9	slit2012	Average student literacy PISA 2012	OECD
10	slit2015	Average student literacy PISA 2015	OECD
11	slit2018	Average student literacy PISA 2018	OECD
12	snum2003	Average student numeracy PISA 2003	OECD
13	snum2006	Average student numeracy PISA 2006	OECD
14	snum2009	Average student numeracy PISA 2009	OECD
15	snum2012	Average student numeracy PISA 2012	OECD
16	snum2015	Average student numeracy PISA 2015	OECD
17	snum2018	Average student numeracy PISA 2018	OECD
18	tsalary_ls_0	Annual statutory teacher salaries in public institutions in USD. Lower Secondary. Starting salary	World Bank
19	tsalary_pr_0	Annual statutory teacher salaries in public institutions in USD. Primary. Starting salary	World Bank
20	tsalary_us_0	Annual statutory teacher salaries in public institutions in USD. Upper Secondary. Starting salary	World Bank
21	gdp_pc	GDP per capita (current US$)	World Bank
22	govexp_educ	Government expenditure on education as % of GDP (%)	World Bank
23	govexp_educ_pr	Government expenditure on primary education as % of GDP (%)	World Bank
24	govexp_educ_sec	Government expenditure on secondary education as % of GDP (%)	World Bank
25	anemia_5	Prevalence of anemia among children (% of children under 5)	World Bank
26	anemia_pregnancy	Prevalence of anemia among pregnant women (%)	World Bank
27	pt_ratio_ls	Pupil-teacher ratio in lower secondary education (headcount basis)	World Bank
28	pt_ratio_pr	Pupil-teacher ratio in primary education (headcount basis)	World Bank
29	pt_ratio_hsec	Pupil-teacher ratio in secondary education (headcount basis)	World Bank
30	gdp_pc1	Average GDP per capita (2000 – 2019)	World Bank
31	gdp_pclt	Average GDP per capita (1970 – 2019)	World Bank

Source: own elaboration

Appendix 2: Detailed Teacher Cognitive Skills

	Pooled	Australia	Austria	Belgium	Canada	Chile	Czech Republic	Denmark	Estonia
Numeracy	288	300	300	308	292	262	305	295	285
Literacy	291	312	292	303	307	263	300	288	294
Domain difference	-3	-12	8	5	-15	-1	5	7	-9
Observations	7,272	248	188	215	834	106	141	413	188
	Finland	**France**	**Germany**	**Greece**	**Hungary**	**Ireland**	**Israel**	**Italy**	**Japan**
Numeracy	317	302	308	282	309	295	270	273	311
Literacy	322	296	301	286	293	300	281	279	319
Domain difference	-5	6	7	-4	16	-5	-11	-6	-8
Observations	221	163	127	150	125	180	250	124	147
	Kazakhstan	**Korea**	**Lithuania**	**Mexico**	**Netherlands**	**New Zealand**	**Norway**	**Peru**	**Poland**
Numeracy	251	287	285	239	304	297	302	223	277
Literacy	256	296	282	257	308	310	304	225	293
Domain difference	-5	-9	3	-19	-4	-13	-2	-1	-16
Observations	293	217	133	103	197	198	279	199	199
	Russian Federation	**Singapore**	**Slovak Republic**	**Slovenia**	**Spain**	**Sweden**	**Turkey**	**United Kingdom**	**United States [1/]**
Numeracy	273	303	294	293	283	306	264	289	288
Literacy	283	300	290	288	290	307	261	299	301
Domain difference	-10	3	4	5	-7	-1	3	-10	-13
Observations	137	193	133	121	183	147	128	310	282

1/ USA score is the average of 2012 and 2018.
2/ Sources: Own elaboration based on Hanushek et al. 2018 and OECD.

Appendix 3: Supporting charts

Figure 3.1: Student and Teacher numeracy scores

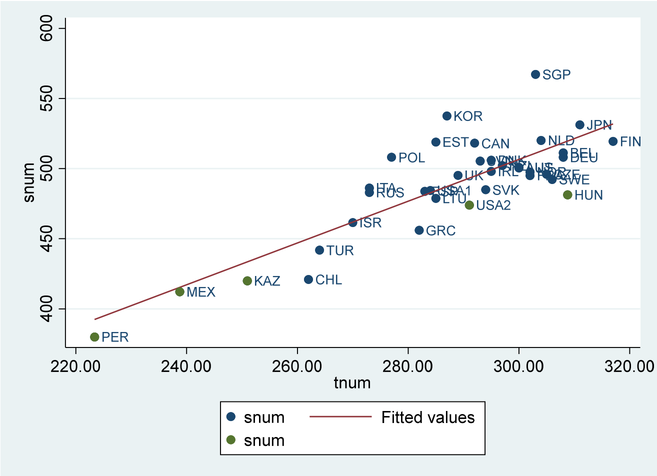
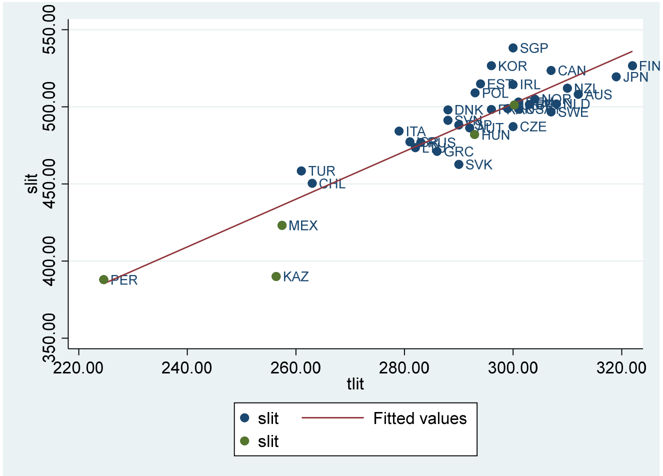


Figure 3.1: Student and Teacher literacy scores



Data Sources: OECD, PIAAC (2012, 2015, 2018) OECD, PISA (2009, 2012, 2015, 2018). Own elaboration based on Hanushek et al. 2018.

Notes: Dependent variable is the nominal average PISA score 2009 – 2018 in numeracy and literacy at the country level for students. Horizontal axis shows the respective score of teacher cognitive skills according to PIAAC using the 2012- 2018 average. Fitted line included.

Figure 3.2: Teacher numeracy and literacy scores

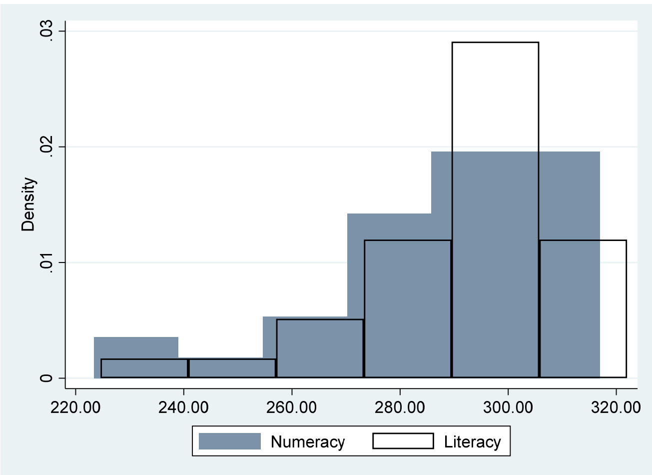
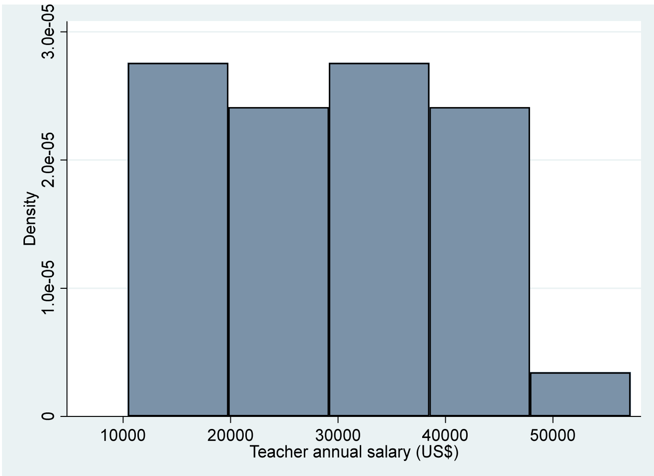


Figure 3.3: Teacher starting salaries



Sources: World Bank, MINEDU, OECD, PIAAC (2012, 2015, 2018). Own elaboration.

Notes: Figure 3 – Histogram skewed to the right containing the average PIAAC Score 2012 – 2018 for numeracy and literacy at the country-level. Nominal points in the PIAAC scale. Figure 4 – Histogram skewed to the left that reflects the distribution of average statutory starting annual salaries at schools in 31 countries. Nominal values expressed in international US$.

Appendix 4 Correlation Matrix

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
(1) snum	1.000																
(2) tnum	0.733	1.000															
(3) slit	0.897	0.675	1.000														
(4) tlit	0.784	0.865	0.841	1.000													
(5) anemia_5	-0.324	-0.327	-0.527	-0.496	1.000												
(6) gdp_pc_PPP	0.389	0.520	0.503	0.585	-0.802	1.000											
(7) tsalary_ls_0	0.267	0.326	0.353	0.357	-0.760	0.763	1.000										
(8) tsalary_pr_0	0.313	0.372	0.407	0.399	-0.796	0.814	0.992	1.000									
(9) tsalary_us_0	0.034	0.095	0.107	0.160	-0.581	0.611	0.919	0.879	1.000								
(10) govexp_educ	0.136	0.235	0.247	0.236	-0.324	0.479	0.370	0.410	0.361	1.000							
(11) govexp_educ_pr	-0.178	-0.373	0.038	-0.121	-0.282	0.179	0.087	0.122	0.162	0.581	1.000						
(12) govexp_educ_sec	0.387	0.522	0.356	0.404	-0.326	0.497	0.469	0.494	0.389	0.811	0.070	1.000					
(13) anemia_5	-0.324	-0.327	-0.527	-0.496	1.000	-0.802	-0.760	-0.796	-0.581	-0.324	-0.282	-0.326	1.000				
(14) anemia_pregna~y	0.128	-0.011	-0.163	-0.151	0.554	-0.599	-0.490	-0.517	-0.410	-0.451	-0.351	-0.329	0.554	1.000			
(15) pt_ratio_ls	-0.535	-0.556	-0.376	-0.372	-0.110	-0.236	-0.045	-0.071	0.106	-0.260	0.277	-0.458	-0.110	-0.155	1.000		
(16) pt_ratio_pr	-0.507	-0.540	-0.527	-0.457	0.361	-0.515	-0.265	-0.310	-0.006	-0.380	0.054	-0.479	0.361	0.211	0.702	1.000	
(17) pt_ratio_sec	-0.469	-0.424	-0.323	-0.305	-0.126	-0.144	0.100	0.075	0.226	-0.200	0.152	-0.300	-0.126	-0.246	0.931	0.689	1.000

Source: Own elaboration.

Appendix 5 Robustness analysis

The application of OLS model 1 indicates a substantive effect of teacher cognitive skills on student achievement,– even when controlling for additional factors such as government expenditure, incidence of anemia, student-teacher ratio, and starting teacher salaries (see Table 5.1 and 5.2). Results are consistent even when applying all the control variables at the same time, suggesting a robust estimate. With an adjusted R2 of around 0.7 in all the configurations, the model seems to explain the cross-country variance in student achievement quite well.

In the most basic configuration, there is a 1.5 impact on student achievement for every point increase in teacher's cognitive skills in numeracy and literacy.

Table 5.1: OLS Teacher cognitive skills on student achievement – Numeracy Skills

Variable	(1)	(2)	(3)	(4)	(5)	(6)
Teacher numeracy	1.489***	1.221***	1.696***	1.379***	1.503***	1.161***
Anemia under 5		X				X
Anemia pregnancy		X				X
Gov expenditure primary			X			X
Gov expenditure secondary			X			X
Avg teacher salary				X		X
Avg student – teacher ratio					X	X
r2_a	0.675	0.698	0.650	0.671	0.670	0.648
sd	.137	.210	.211	.162	.198	.270

Data Sources: World Bank, MINEDU, OECD, PIAAC (2012, 2015, 2018) OECD, PISA (2009, 2012, 2015, 2018). Own elaboration.

Table 5.2: OLS Teacher cognitive skills on student achievement – Literacy Skills

Variable	(1)	(2)	(3)	(4)	(5)	(6)
Teacher Literacy	1.547***	1.284***	1.537***	1.358***	1.615***	1.292***
Anemia under 5		X				X
Anemia pregnancy		X				X
Gov expenditure primary			X			X
Gov expenditure secondary			X			X
Avg teacher salary				X		X
Avg student – teacher ratio					X	X
r2_a	0.788	0.793	0.795	0.820	0.785	0.801
sd	.147	.173	.148	.127	.186	.196

Data Sources: World Bank, MINEDU, OECD, PIAAC (2012, 2015, 2018) OECD, PISA (2009, 2012, 2015, 2018). Own elaboration.

*Notes: Dependent variable is the average PISA Score 2009 – 2018 for numeracy (table 5.1) and literacy (table 5.2). Teacher salary and student-teacher ratios were converted into a single average at the school level (primary, lower secondary, and upper secondary) following the results of the correlation matrix. Average anemia incidence at the country-level from 1995 to 2004. Government expenditure expressed as % GDP (the average 2007 – 2016). Average starting salary at country-level from 2009 - 2018. Average pupil-teacher ratio from 2008 – 2017. All configurations include robust standard errors. Significance levels are as follow: *p < 0.10, **p < 0.05, ***p < 0.01.*

Appendix 6: Salaries and teacher skills

Figure 6.1: Salaries and Teacher numeracy skills

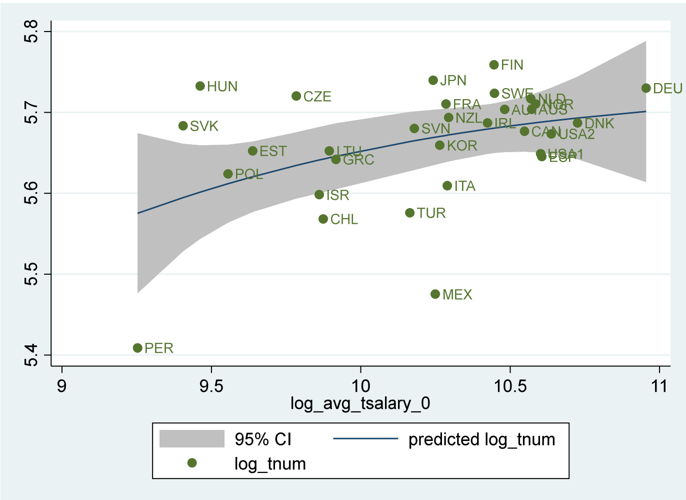
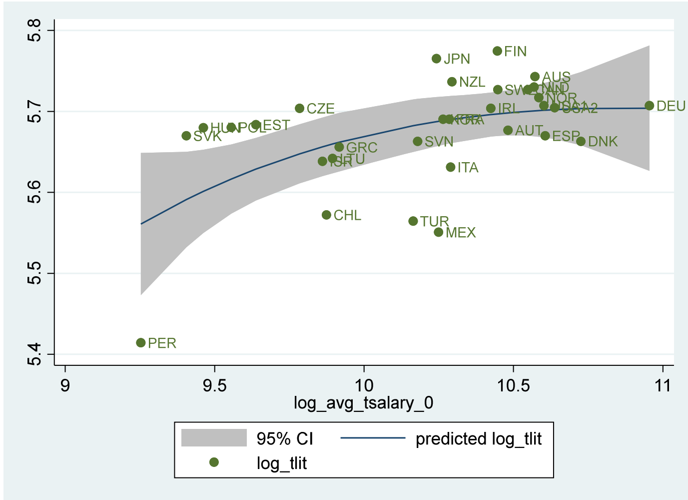


Figure 4.2: Salaries and Teacher literacy skills



Data Sources: World Bank, MINEDU, OECD, PIAAC (2012, 2015, 2018). Own elaboration.

Notes: Dependent variable is the logarithmic transformation of the average PIAAC Score 2012 – 2018 for numeracy and literacy at the country-level. Combined average statutory teacher salaries at schools (primary, lower secondary, and upper secondary) from 2009 to 2018. Polynomial fitted line.

Appendix 7. Student skills and GDP per capita

Figure 7.1: Student skills and GDP per capita (2000–2019)

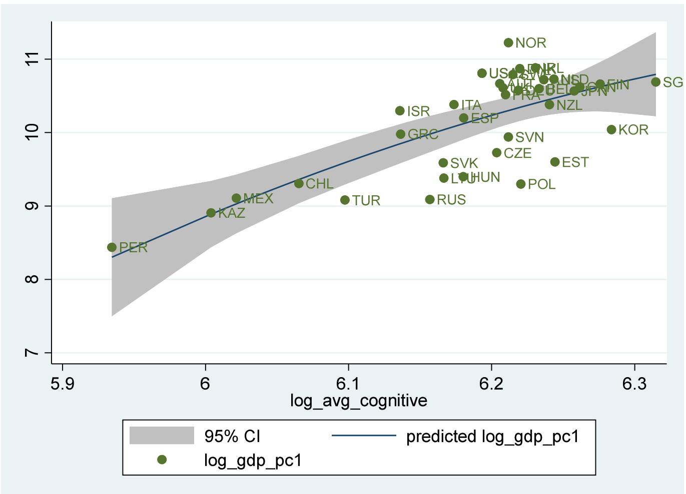
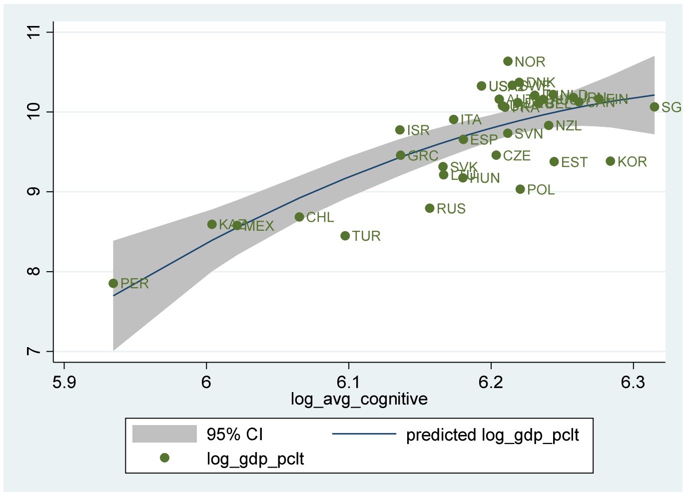


Figure 7.2: Student skills and GDP per capita (1970–2019)



Data Sources: World Bank, OEC, PISA (2000, 2003, 2006, 2009, 2012, 2015, 2018). Own elaboration.

Notes: Dependent variable is the logarithmic transformation of the average GDP per capita during the period 2000 – 2019 (figure 8) and 1970 – 2019 (figure 9). The cognitive skills combine the average skills for literacy and numeracy scores during the whole period of the PISA project to date (2000 – 2018). Polynomial fitted line.

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