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Schooling Environment and Students' Performance: An Empirical Analysis at Aggregate Level.

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Dedication

The thesis is dedicated to every parent and teacher, who strive to create a bright future for the next generations.

Abstract

Empirical research on human capital over the last few decades has focused on multiple kinds of measures, incorporating resources, student achievement, school attainment and others. This paper provides support for the positive relationship between GDP per capita growth and the quality of the labor force, proxied by international student test scores, closely following the assumptions and procedures of Hanushek and Kimko (2000), by using modern data. The main results coincide with Hanushek and Kimko (2000), while there is variation in others. Specifically, the baseline cross-sectional regression of growth, which includes the variables of the initial income, the parental education (or schooling quantity), the population growth rate and the labor force (or schooling) quality of different countries is estimated by using an observed and a predicted (or augmented) sample of countries. While the outcomes of the former show significance of schooling quality over quantity, the latter concludes with the importance of high quality, which should accompany the negative direct effects of quantity on growth. Other conclusions refer to the efficiency of the teacher salaries on student performance and the role of educational resources. Moreover, the cross-sectional models of growth seem robust when East and South East Asian high performing countries are excluded. Finally, the growth and human capital quality relationship is estimated in a more direct framework, by using a set of panel regressions. The results in this case are similar to the cross-sectional counterparts, although different specifications may have to be taken into consideration.

Keywords: Human capital; schooling quantity; schooling quality; school resources.

Acronyms:

GCDL: Global Change Data Lab.
H-K: Hanushek and Kimko (2000).
IAEP: International Assessment of Educational Progress.
IEA: International Association for the Evaluation of Educational Achievement.
NAEP: National Assessment of Educational Progress.
OECD: Organisation for Economic Co-operation and Development.
TIMSS: Trends in International Mathematics and Science Study.
WDI: World Development Indicators.

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1. Introduction

Human capital and its impact on growth has been a major topic of theoretical and empirical research for many years now. As the datasets expand both in time and in cross section, economists are led to significant conclusions on the importance of education on peoples' incomes and countries' economic growth. In the first chapter, some of the research on this subject of the last two decades is shown, the theoretical background of the paper is explained and the methodology used is briefly described.

1.1 Related literature

Beginning with the literature review, the most important research, which is closely followed for the greatest part of this paper, is Hanushek's and Kimko's "Schooling, Labor-Force Quality and the Growth of Nations" (2000). Using a sample from 1960 to 1990, they add variables of human capital quality and quantity along with others, the first being a multiplicative measure of international student assessments and the second being the intertemporal mean of the average years of adult schooling. Their main argument is that human capital importance is signified in its' quality, along its' quantity, while their results show a robust indication of the former overlapping the significance of the latter, when it comes to defining a country's economic growth.

When speaking of quality, a determining factor that cannot remain unnoticed is the efficiency of wages. This issue is addressed by Loeb and Page (2000), who include real and relative wages in a regression among other school characteristics, that affect the teaching conditions and consequently the drop-out rates. The sample they use originates from USA school districts from 1960 to 1990. While real wages depict the purchasing power, the inclusion of the ratio of teacher wages to those of other workers considers the cost of opportunity the teachers are burdened with, having chosen this specific career. They conclude that real wages, relative wages and other factors of teaching and working conditions have a significant impact on high schools' drop-out rates.

An interesting attempt on explaining the differences in growth by using human capital is given by Barro (2001). He regresses the real GDP per capita growth rates on several human capital resource variables, schooling quantity, schooling attainment and student test scores in mathematics and science for 100 countries from 1965 through 1995. He finds both quantity and quality to be important, with the former having a larger impact on growth rates. Therefore, his conclusions differ from Hanushek and Kimko (2000), who suggest that quantity is not significant when quality enters the equation.

Woessmann (2003) estimates the effects of family, student and school resources' characteristics on student performance, using international data. He finds that country differences in achievement are mainly attributed to institutional variation, such as different types of examinations, curriculum, restriction on teacher unions and parental behavior. Differences in resources do not seem to affect achievement similarly.

Figlio and Kenny (2007) use US data of students, schools, teachers and families to determine the effect of teacher merit pay on student performance. While they find a positive relationship, they interpret the result in two different ways. Specifically, they suggest the existence of wage efficiency dynamics, as the teachers have a high incentive to work harder, in the presence of a possible merit pay. They contrast this argument by implying the result can be spurious, since ”schools that are more effective in other difficult-to-measure ways are more likely to adopt individual teacher incentives” (Figlio and Kenny, 2007), meaning high performance could be emanating from other factors. Kingdon and Teal (2007) present similar research, referring to teacher performance pay in schools in India. Controlling for student ability, family characteristics and resource availability, they conclude on a positive relationship between performance pay and student achievement. They also reveal that such effects are stronger in private rather than public schools.

Hanushek and Woessmann (2008) use international student test scores to proxy the cognitive skills of a population. They find skills to be a major factor of economic development, while also showing school attainment is not as important. On the contrary, Breton (2011) challenges these results, arguing that both school attainment and student performance can yield a significant relationship with economic growth, given a more adequately specified model.

Woessmann (2011) also applies the wage efficiency framework on the quality of human capital, by approaching the teachers’ performance pay. Combining data from thousands of students across 28 countries, he regresses the PISA 2003 score on the performance pay, while controlling for other characteristics of the students, teachers, schools, countries, regions and cultures. His results indicate a strong relationship between performance pay and high educational achievement. Another rather interesting study on the human capital quality is attributed to Hanushek and Woessmann (2012), in which they relate the economic growth of nations with the overall cognitive skills’ distribution among other characteristics. They use the data of 64 countries from 1960 to 2000. While their study is based on Hanushek and Kimko (2000), the construction of the skill-measurement variable includes the families’ and schools’ contribution along with the skills of each individual. By regressing the growth rates on the cognitive skills’ measure, the school attainment and the GDP per capita, they reveal a strong positive relationship between skills and economic performance.

Grissom and Strunk (2012) associate student performance with teacher salary schedules. They differentiate the salary schedules into ”frontloaded” and ”backloaded”, the former meaning that novice teachers enjoy a higher salary increase per year of experience in relation to veteran teachers, and the latter meaning the opposite. They find that frontloaded compensation plans are positively related with student test scores, therefore increases in payment early in a teacher’s career is associated with high achievement. Hendricks (2015) regresses student achievement on teacher characteristics and examines the effects of salaries on teacher attrition, using panel data from Texas’ public schools. To achieve this, he uses Texas’ state public school student test scores and teacher data about certification scores and salaries. He finds that certification scores indicate a teacher’s performance, while higher salaries and differential pay attribute to the retainment of high-ability staff.

Bernal et. al. (2016) estimate the effect of teaching quality on student achievement in reading and mathematics by using a proxy model of teachers’ and school resources’ characteristics. On the one hand, teaching quality proxies include certifications, years of schooling and college courses. On the other hand, resource quality is proxied by class size and different measures of pupil to staff ratio. Their panel regression results in significant coefficients with the correct sign for each proxy-variable.

A different approach on the subject is given by Coenen et. al. (2018), in which they derive evidence of the importance of teacher characteristics on students’ achievement. This task is carried out by a systematic review of 96 studies, related to the two aforementioned definitions. Their findings reveal the characteristics that have the largest impact on students' achievement. Specifically, they point out the importance of the ”subject-specific Master's degrees in math and science” (Coenen et. al. 2018), the quality of the college that the teacher attended, and the teaching experience. Moreover, they find no evidence of a relation between general teaching certification and student performance, except if the teacher is certified on specific subjects, in which case there consists a positive relationship.

1.2 Theoretical background

Moving on to the theoretical background, this paper follows an empirical approach, to define the importance of the quality of human capital on countries' economic growth, using modern data. As such, Lucas' model of endogenous growth (1988) is considered the backbone of this research, based on which the differences in growth between nations are explained by differences in human capital. Of course, accumulation of human capital is taken into account, as well as the quality of the accumulated human capital, following the methodology of H-K (Hanushek and Kimko (2000)). Apart from that, an aspect of the neoclassical theory is inserted into the model, as the variable of the initial income is considered a basic component for the greatest part of the explanation of growth volatility. In that manner, the initial income addresses the existence of the Inada conditions, based on which countries with high initial income are expected to have low rates of growth. Moreover, the theory of wage efficiency is added to the equation, by regressing the human capital quality measures to the intertemporal mean of teacher wages for the selected time period. Regarding, the term used differs from Loeb's and Page's (2000) real and related wage, as well as Woessmann's (2011) performance pay, and instead the statutory teacher salary is used, which includes both the annual wage and the bonuses.

1.3 Adopted methodology

Finally, the methodology and steps of H-K are closely followed, to recreate the human capital quality measures with modern data. Their period spans from 1960 to 1991 and refers to 31 countries, while this paper uses the time range of 1990-2019 for 58 countries. Their regressions are mainly cross-sectional, comprised of the intertemporal means of GDP per capita growth, adult schooling quantity, initial income and other school resource variables and indicators, while they apply a multiplicative method to construct two human capital or just schooling quality measures. These are calculated by using international student assessments in mathematics and science. They use student scores from the *International Association for the Evaluation of Educational Achievement (IEA)*, the *International Assessment for Educational Progress (IAEP)* and the *National Assessment of Educational Progress (NAEP)*. The former two provide data for the calculation of their first quality measure QL1, the value which is normalized to a mean of 50. The latter dataset is used to form their second quality measure QL2, which is normalized to the US national mean and provides an international comparison over time. While the recreation of QL2 in this paper also emanates from the *NAEP*, the data used for QL1 are derived from the *Trends in International Mathematics and Science Study (TIMSS)*, which nonetheless has the same source as the *IEA*. Unfortunately, the data used by H-K ranging from 1960-1990 are not widely available.

2. Data and Variables

This chapter has the objective of analytically explaining the nature of all of the variables and datasets used in the following regressions. Our data emanates from different sources; the *IEA*, the *NAEP* the *World Development Indicators Databank of the World Bank* (*WDI*), the *Organization for Economic Co-operation and Development (OECD)* statistics, the *Global Change Data Lab (GCDL)* and the *Global Data Lab (GDL)*. To clarify, student test scores originate from the *IEA* and specifically from the *Trends in International Mathematics and Science Study (TIMSS)* and from the *NAEP*, while the selected schooling quantity data comes from the *GCDL* database, which is based on the *Oxford Martin School - University of Oxford*. The teacher salaries data was collected from the *OECD* and the source for the other variables (described in the following sections) was the *WDI* (*World Development Indicators*).

2.1 Student achievement data

The *TIMSS* database provides student test scores for 7 different years, each having a 4- year gap, ranging from 1995 through 2019. The achievement data is also differentiated in grade (4th or 8th) and subject (Science or Mathematics), resulting in a total of 26 different assessments (the 1999 *TIMSS* only tested students of the 8th grade). Although reading assessments were also available, they were not included in accordance with H-K, due to the varying complexity of different languages across nations. In other words, a language might be more difficult to learn than others, resulting in spurious conclusions, while knowledge of mathematics and science provides a more adequate comparison. Each assessment involves a different pool of countries, some of which can be considered as ”core” and the rest of them as a ”random draw” from the world distribution. While the *TIMSS* is used for the creation of our first schooling quality measure, the *NAEP* data forms the second measure, in accordance with the methodological procedures of H-K, which are described analytically in the next chapter of our paper. Totally, 1074 observations of student test scores across the aforementioned time period are collected. Of course, many of these are excluded due to a lack of data on other variables (schooling quantity, GDP per capita, resource variables etc) or for robustness reasons in the panel regression. An interesting note at this point is that H-K use test score data from the *IEA, IAEP* and *NAEP* based on student age (9 or 13 year-old students), while the TIMSS and NAEP dataset used in this paper refers to student grade (4th or 8th grade students). Unfortunately, the complete assessment dataset used by H-K is not entirely available online, and for that reason, we begin the cross-sectional analysis from 1990, instead of 1960. As for the panel regression, the collected achievement data refer to 8 assessments for the period of 1985 through 2015, by combining information from the early dataset used in H-K, as well as the recent one used in the cross-country regressions. Table A.1 in the Appendix provides a list of the sources and time ranges of the data used in our research in comparison to the H-K datasets.

2.2 Schooling quantity data

The schooling quantity variable refers to the average years of schooling of the adult population (25 and over) of each country. Given the cross-country aspect, it is calculated by extracting the 30-year intertemporal average of all available information for every country in the period of 1990-2019. Two sources were considered for the formation of the variable; The *GCDL* and the *GDL*. The former is based on the Oxford Martin School - Oxford University, and provides estimates for the period of 1870-2017 for a large number of countries. The estimates in this sample are derived from Barro-Lee (2018) for the 1950-1990 period and the United Nations Development Programme, Human Development Report (UNDP HDR) (2018) for the range of 1991-2017. The latter (GDL data) originates from the Institute for Management Research - Radboud University and covers the period of 1990-2021. There are two main differences arising in the nature of these datasets, which lead to some implications. First of all, they do not cover the same time-ranges. Second, the *GCDL* sample is constructed by estimations of schooling quantity, while the *GDL* is based on national survey data, meaning there is a chance of bias in the collected observations. Therefore, the samples cannot be integrated, since there are significant differences in many observations, which refer to the same year and country. Consequently, the *GCDL* dataset was selected, since it covers a wider time-range, even though the scores of 2019 (a total 4 assessments) are ”sacrificed” for this reason in the panel regressions.

2.3 The other variables

H-K use many other variables to determine the growth of nations. These include, but are not limited to, the real GDP per capita growth, which is treated as the most major dependent variable, the initial income or the real GDP per capita in 1960, the population growth and several resource variables, such as the pupil to teacher ratio, the current public expenditure per student in public institutions, the total government expenditure as a ratio of the GDP, the rate of school enrollment and others. Most of the variables included in the regressions of this paper are similar to those of H-K, while many more that were tested are not shown in the following tables. Undoubtedly, there are many resource and school enrollment variables that can be used as independent in order to determine the growth or the schooling quality of a population. Yet, the core of this research tends to follow the footsteps of H-K, to provide an adequate comparison of the extracted results. Generally, the variables of growth, schooling resources and enrollment are formed by calculating the 30-year intertemporal average of all available information for every country, similar to the case of the schooling quantity. Needless to say, the panel regressions provide a more direct approach of the discussed relationships of growth and human capital.

3. Methodology

In this chapter, the related equations, theoretical background and adopted methodology are discussed in detail. Generally, the regressions of this paper follow the core of H-K except the wage efficiency regression and the panel approaches of the growth model.

3.1 Basic assumptions

Regarding the cross-country regressions, all of the basic assumptions of H-K are adopted in this paper. First of all, the intertemporal 30-year average of every included variable is considered to be stable, thus every country is assumed to have a stable value of schooling quantity, growth and population rate, school resources and enrollment rate for every year in the period of 1990-2019. Of course, it is quite evident why this aspect is adopted, since we refer to cross-sectional regressions. Second, the participating countries of every assessment from 1995 through 2019 are considered to be selected randomly. Although some countries are included in every assessment regardless of year, grade or subject, the majority of the participants seem to enter the tests at a discontinued or random frequency. Last but not least, the educational systems change slowly over time. Therefore, the teaching culture, the institutions and the curriculum of every nation remain stable over the 30-year period.

Evidently, the panel regressions are excluded from two of the three aforementioned assumptions. Specifically, the assumption of the intertemporal stability of the means naturally coincides only with the cross-sectional regressions, while the panel approach takes the different yearly effects into account. Moreover, the possible impact of institutional differences across countries is also considered by applying fixed effects. There are two panel regressions in this paper. The first is the production of student test scores, in which the normalized test scores of every available country and year are regressed to several independent variables, to determine the sources of their variation. The second is the panel growth model, which is a recreation of the baseline cross-country regression of H-K, but with a panel approach. In that case, the impact of cross-sectional and time heterogeneity on growth rates is adequately measured.

3.2 The core equations

The theory behind the regressions in the next chapter is described by the equations of growth, school resources' quantity and Labor-Force quality, adopted by the framework of H-K. The backbone of these equations is an endogenous growth model with the inclusion of human capital. Therefore, human capital quantity and quality measures are used to explain differences in growth between countries. The core equations are the following:

$$g_i = X_i * a_1 + QL_i * a_2 + e_i \tag{3.1}$$

$$R_i = W_i * b_1 + g_i * b_2 + v_i \tag{3.2}$$

$$QL_i = Z_i * c_1 + R_i * c_2 + u_i \tag{3.3}$$

The first equation (3.1) shows that a nation's *i* economic growth *g* is determined by the quality of its Labor-Force *QL* along a vector of other variables *X*. The second equation (3.2) clarifies that a nation's *i* quantity of school resources *R* is affected by its growth rate *g* and some other variables *W*, while the last one (3.3) explains that the Labor-Force quality *QL* of a nation *i* is formed by the quantity of the school resources available along with other factors, given by *Z*. Consequently, growth is indirectly determined by government policies through their impact on the Labor-Force quality. For example, the total public expenditure on education or the pupil to teacher ratio can be directly determined by the officials, but their impact on growth is only visible through their efficiency on student achievement, which forms the Labor-Force quality measures. These effects are examined in the table of the production of student achievement in the next chapter, while a direct approach is also undertaken in another set of regressions, in which the impact of quality and quantity measures on growth is put in comparison.

Following the methodological procedures of H-K, the equation (3.3) is undertaken for the estimation of the Labor-Force quality *QL* measure and consequently, the growth rates *g*, while the quantity of the school resources *R* is considered exogenous. For the quality estimates to be consistent, it must be that the error terms *v* and *u* of the equations (3.2) and (3.3) are uncorrelated. The reason why this task is undertaken is to observe the impact of school resources and other variables, such as family educational background and population growth, on student achievement and consequently the quality of the Labor-Force across years and countries.

3.3 Calculation of the quality measures

There are two Labor-Force quality measures constructed by H-K, which are also adopted in this paper. Both are formed in a similar manner with their difference lying to the source of their mean, based on the methodology described in Hanushek and Kim (1995). To begin with, the first quality measure QL1 of a country *i* is formed by combining all available information of student achievement data for the time-range of 1995-2019. Each test score of every assessment is normalized to a mean of 50, while the standard error of every score is also transformed to that scale. Therefore, the Labor-Force quality measure of a country is the intertemporal weighted average of its test scores, normalized to a mean of 50, the weights of each score being its normalized inverse standard error. This definition can be described by the following equation:

$$QL1_i = \frac{\frac{A_{i1}}{s_{x.A1}} + \frac{A_{i2}}{s_{x.A2}} + \ldots + \frac{A_{in}}{s_{x.An}}}{\frac{1}{s_{x.A1}} + \frac{1}{s_{x.A2}} + \ldots + \frac{1}{s_{x.An}}} \qquad (3.4)$$

where

- *A* is the test score of a country *i*, normalized to a mean of 50.
- *n* is the total number of assessments a country has participated in.
- $s_{x.A}$ is the standard error of each test score, also normalized to the score scale.

To be more specific, the normalized values to a mean of 50 of the test scores and their standard errors are calculated as such:

$$A_{ij} = \frac{T_j}{MT_k} * 50 \qquad (3.5)$$

$$s_{x.Aj} = \frac{\sigma_{x.Tj}}{MT_k} * 50 \qquad (3.6)$$

where

- *T* is the raw test score of a country *i*.
- *j* = 1, 2, ..., n indicates the different test a country has participated in.
- *MT* is the mean score of every different international assessment conducted in a number of countries.
- *k* refers to the different cohort of the mean.
- $\sigma_{X.Tj}$ is the raw standard error of a test score *T*.

The second Labor-Force quality measure, QL2, is constructed similarly, but instead of normalizing to a mean of 50, we do so to the national intertemporal mean of the USA for that subject and grade. It is clear that the QL1 measure uses a more disaggregated mean, since the assessments refer to a large range of countries for every year, while QL2 incorporates the intertemporal mean scores of different subjects and grades, emanating from US students. For the test scores of *TIMSS* that do not coincide in the years of *NAEP*, Hanushek and Kim (1995) suggest discarding the related values or simply using the test score normalized to a mean of 50 both for QL1 and QL2. The second method is adopted in H-K, as well as in this paper, in order not to lose observations. At this point it is important to note that in most of the test years in the dataset of this paper, the international *(TIMSS)* and US *(NAEP)* scores do not coincide, since the former refers to 1995, 1999, 2003, 2007, 2011, 2015 and 2019, and the latter covers the years 1992, 1994, 1996, 2000, 2003, 2005, 2007, 2009, 2011, 2013, 2015, 2017, 2019 in Mathematics achievement and 1996, 2000, 2005, 2009, 2015 and 2019 in Science achievement. It is evident that strictly applying the approach of Hanushek and Kim (1995) would result in virtually the same variables, providing little additional information to the nature of their means. For the quality measures to be more different in value, we have to assume that the US national achievement changes abysmally in the course of one year, so that the international scores of 1995 and 1999 can be ”paired” to the US means of 1996 and 2000. As for the other ”gaps” in the Science achievement scores, we compute the normalized test scores exactly as recommended by Hanushek and Kim (1995). Although this assumption does not negatively affects the outcomes of the regressions, it still results in quite a high correlation of approximately 99.5% between QL1 and QL2. The quality measure QL2 is described in detail in the following equation:

$$QL2_i = \frac{\frac{B_{i1}}{s_{x.B1}} + \frac{B_{i2}}{s_{x.B2}} + ... + \frac{B_{in}}{s_{x.Bn}}}{\frac{1}{s_{x.B1}} + \frac{1}{s_{x.B2}} + ... + \frac{1}{s_{x.Bn}}} \quad (3.7)$$

where similarly as before:

- *B* is the test score of a country *i*, normalized to the US national mean.
- *n* is the total number of assessments a country has participated in.
- $s_{x.B}$ is the standard error of each test score, also normalized to the score scale.

The scores and standard errors in this case are normalized as such:

$$B_{ij} = \frac{T_j}{USMT_p} * 50 \quad (3.8)$$

$$s_{x.Bj} = \frac{\sigma_{x.Tj}}{USMT_p} * 50 \quad (3.9)$$

where

- *T* is the raw test score of a country *i*.
- *j* = 1, 2, ..., n indicates the different test a country has participated in.
- *USMT* is the US national intertemporal mean score of every different subject and grade.
- *p* refers to the different cohort of the mean.
- $\sigma_{X.Tj}$ is the raw standard error of a test score *T*.

As for the growth panel regressions, only the first quality measure QL1 is used to determine the effects of human capital quality and quantity on GDP per capita growth, due to the unavailability of earlier US data for Maths and Science. It is formed by a slightly different methodology, since the yearly effects are also taken into account. Specifically, it is calculated as the yearly weighted average of all available student test scores for each year and country, the weights being the inverse standard errors of every score. In both the cross-sectional and the panel case, the inverse standard errors are used as weights to ”reward” information of good quality. In other words, test scores with low standard error in their mean entail more representative observations in our sample.

4. Results

4.1 Introduction

This chapter presents the results of the regressions based on H-K, as well as some extra variations. Initially, the summary statistics and correlation matrix of the baseline regression are presented, with their most major points and implications commented. After that, the production of the test scores (normalized to the mean of 50) is shown, therefore clarifying the determinant variables of the student achievement across countries and years. Next, the baseline regression is described in detail, therefore we obtain valuable information about the underlying relationships of growth and the human capital measures of quantity and quality. Following H-K, a prediction model of Labor-Force quality is constructed, to augment the initial sample of countries. The augmented sample does not coincide with the respective results of H-K, but it signifies another kind of relationship between human capital quantity and quality. We also apply a robustness check, by excluding several countries of East and Southeast Asia, in which high growth rates and high performance in school has been observed[1]. Moreover, a wage efficiency aspect is taken into account, by regressing our quality measures on teacher salaries and several other variables, and a comparison of alternative measures of human capital is undertaken by adding resource variables directly into the growth estimation. Finally, we approach the growth model more directly in the panel regression, therefore estimating the yearly and cross-country effects.

4.2 Summary statistics and correlation of the baseline and prediction model

Some interesting information is derived by the initial tables of summary statistics and correlation matrices. First of all, it is evident that our quality measures QL1 and QL2 are almost identical, since they have very close means in Table 4.1. This result can be more adequately drawn by looking at their correlation coefficients in Tables 4.2 and 4.3; They are correlated at almost 99.6%, making them virtually the same. H-K found a correlation of about 92% between the two measures, which can also be considered high, although significantly lower than the results of this research. Given the other coefficients in the correlation matrices 4.2 and 4.3, multicollinearity doesn't seem to be a problem, even in the case of the high correlation between the quality measures QL1 and QL2, and schooling quantity SCH. Indeed, the Variance Inflation Factor test was conducted in every case, and resulted in the absence of multicollinearity, with the exception of 2 regressions in the augmented sample, shown later in the results.

Evidently, GROWTH is the dependent variable of the majority of the following regressions, while I90, SCH, POPG, QL1 and QL2 are the major independent variables. Specifically, I90 approaches the differences in growth rates in a neoclassical aspect, based on which the initial GDP per capita of a country affects its growth rates. H-K use the initial income in 1960, in order to determine its effect on growth for the 31-year period of 1960-1990, while we use the 1990 income I90 to conduct a similar estimation for the

[1] The East Asian countries selected as "high performing" are based on the World Bank Blogs article; Which region has the smartest kids? According to the OECD it's East Asia (Patrinos et. al. 2017). Although it refers only to 2015 data, this article is considered reliable enough, given the assumption of the slow change of educational systems over the course of the 30-year period we examine.

1990-2019 (30-year) period. Of course, we expect there is a negative relationship between growth and initial GDP per capita, given that countries with low income have the opportunity to grow much faster, compared to high income countries. This is the case for every cross-sectional regression, while there are some implications in the panel type. Other standard variables we use are the education of parents, proxied by the average quantity of schooling SCH, and the population growth POPG. School resources are also taken into account, such as the pupil to teacher ratio in primary and secondary schools (PTPRI and PTSEC respectively), the ratio of current public educational expenditure to total expenditure in public institutions (CEXP), the ratio of total government expenditure on education to GDP and several others, not shown in the results. Finally, we incorporate different types enrollment rates in the prediction models, to estimate the effect of the ”absence” of students from education on their performance[2]. Notably, our baseline regression includes 58 countries, while H-K had an estimation of 31 countries.

[2] School enrollment rates are differentiated in Gross or Net in primary or secondary school. Based on the World Bank Development indicators, the gross enrollment rate is the ratio of total students enrolled in school regardless of age to the population that officially corresponds to the related level of education, while the net enrollment is the ratio of students of official school age who are actually enrolled to the total population of the related age.

Table 4.1: **Summary Statistics of the Baseline Regression.**

Variable	Median	Mean	Standard Deviation	Minimum	Maximum	Observations
QL1	50.46	48.52	7.12	22.96	61.39	71
QL2	50.95	48.80	7.18	23.14	61.76	71
POPG (Population growth rate x100)	0.85	1.03	1.36	-1.11	6.28	71
GROWTH (GDP per capita growth x100)	1.92	2.15	1.35	-1.14	5.48	71
I90 (Initial income in 1990 in 1000s of constant 2015 $US)	8.61	15.90	16.36	0.01	70.06	58
SCH (Average adult schooling quantity in years)	10.08	9.34	2.35	1.72	12.90	71
PTPRI (Primary pupil-teacher ratio)	17.15	18.36	6.66	8.86	40.37	71
PTSEC (Secondary pupil-teacher ratio)	12.23	14.04	5.44	7.11	33.17	69
ENPRI_N (Primary school net enrollment rate x100)	94.44	92.61	6.50	63.03	99.68	70
ENSEC_N (Secondary school net enrollment rate x100)	87.70	82.27	14.56	34.08	99.66	69
CEXP (Current public education expenditure/ total expenditure in public institutions x100)	91.49	90.16	5.38	71.58	96.99	67
TEXP_GDP (Government expenditure on education/GDP x100)	4.87	4.72	1.31	1.82	7.85	71

Table 4.2: **Correlation matrix of the Baseline Regression Variables.**

(Dependent: GROWTH)

	QL1	QL2	POPG	I90	SCH	GROWTH
QL1	1					
QL2	0.9957	1				
POPG (Population growth rate x100)	-0.4880	-0.4286	1			
I90 (Initial income in 1990 in thousands of constant 2015 $US)	0.4901	0.5005	0.0828	1		
SCH (Average adult schooling quantity in years)	0.7973	0.7845	-0.4359	0.5587	1	
GROWTH (GDP per capita growth x100)	0.2006	0.2005	-0.2528	-0.3632	0.0475	1

Table 4.3: **Correlation Coefficients of the Prediction Model Variables.**

(Dependent: QL1 &QL2)								
	QL1	QL2	POPG	SCH	PTPRI	ENPRI_N	CEXP	TEXP_GDP
QL1	1							
QL2	0.9956	1						
POPG (Population growth rate x100)	-0.4978	-0.4605	1					
SCH (Average adult schooling quantity in years)	0.7994	0.7906	-0.4175	1				
PTPRI (Primary pupil-teacher ratio)	-0.6266	-0.6265	0.2348	-0.6163	1			
ENPRI_N (Primary school net enrollment rate x100)	0.6691	0.6665	-0.2646	0.5181	-0.5577	1		
CEXP (Current public education expenditure/ total expenditure in public institutions x100)	0.3578	0.3292	-0.4648	0.3922	-0.2969	0.4161	1	
TEXP_GDP (Government expenditure on education/GDP x100)	0.0237	-0.0045	-0.1611	0.1894	-0.3047	0.1758	0.2381	1

4.3 Production of student achievement

Before moving to the core of our research, we shall present a panel regression of the test results normalized to a mean of 50 on several school resource variables, the population growth rates and the schooling quantity in Table 4.4. In columns (1)-(3), we can observe that the parental education background is consequently significant at the 1% confidence level with a coefficient ranging from 1.4 to 1.6. The population growth rate is significant with a negative sign in columns (1) and (2), where the primary pupil to teacher ratio and current expenditure are selected as the independent resource variable respectively, while it becomes insignificant when assessing the total government educational expenditure per student to GDP per capita. We can infer that resource variables have a weak effect on the test scores, so that differences in student performance are mostly attributed to the size of the population and especially to the parental education. H-K found similar results on the resource variables. Next, columns (4)-(6) address the same estimation but with applied fixed effects on time, grade (4th or 8th), subject (science or mathematics) and region (Asian, African or Latin American country). Although H-K only tested for time-period effects, we expanded the treatment to many other possible determinants of the test scores. As a result, the coefficient of SCH and POPG are quite lower, while the effects of school resources are still insignificant. Adding the school enrollment rate (not shown) resulted in inconsequential significance of resource, population and enrollment coefficients, while the quantity of schooling remained significant. Taking into account different resources (secondary school pupil to teacher ratio, total government expenditure on education to GDP, current expenditure in primary and secondary schools) and enrollment types (gross and net enrollment in primary or secondary schooling) did not change the outcome. Therefore, based on these datasets we can safely say that the most important factor of a student's achievement in tests is the background of the parental education.

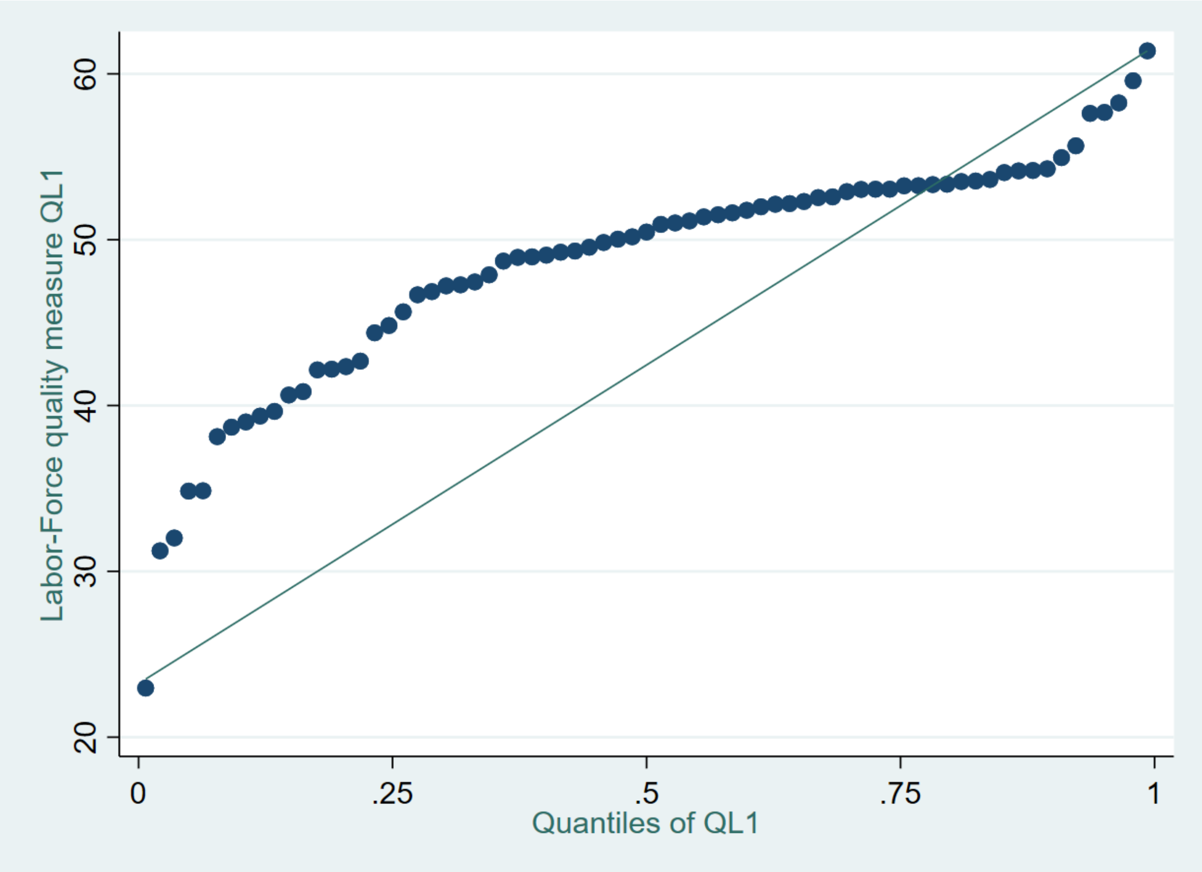
Table 4.4: **Production of Student Achievement (1990-2019).**

Dependent variable: Test result normalized to a mean of 50						
Independent variables	(1)	(2)	(3)	(4)	(5)	(6)
Schooling quantity (t-1) (SCHt1)	1.421*** (0.218)	1.629*** (0.240)	1.483*** (0.277)	1.466*** (0.256)	1.433*** (0.297)	1.222*** (0.295)
Population growth (t-1) (POPGt1)	-0.735*** (0.162)	-1.091*** (0.420)	-0.011 (0.416)	-0.682*** (0.161)	-0.763* (0.428)	-0.305 (0.399)
Primary school pupil-teacher ratio (t-1) (PTPRIt1)	-0.095 (0.075)			-0.067 (0.079)		
Current public expenditure on education as a % of total expenses in public institutions (t-1) (CEXPt1)		-7.991 (7.323)		-4.862 (6.864)		
Total government educational expenditure in primary schools per student/GDP per capita (t-1) (TEXPST_PRIt1)			2.687 (7.534)			2.003 (6.499)
Constant	37.176*** (3.158)	41.711*** (7.074)	34.264*** (2.878)	37.247*** (3.092)	42.362*** (7.208)	40.201*** (3.216)
R-squared	0.57	0.55	0.51	0.65	0.66	0.70
Time fixed effects	No	No	No	Yes	Yes	Yes
Grade and subject fixed effects	No	No	No	Yes	Yes	Yes
Regional fixed effects	No	No	No	Yes	Yes	Yes
Number of observations	206	116	118	205	116	117
Number of countries	69	50	49	69	50	49

Notes:

1. The significance level of each coefficient is noted by the asterisks as such: 1%***, 5%** and 10%*.
2. The standard errors are shown in parentheses below each coefficient.
3. A test score in Maths or Science at grade 4 or 8 was selected for each available year for each country, resulting in a panel regression.
4. Time, grade, subject and regional fixed effects were tested separately for each case (not shown), giving similar results in almost every case.

Figure 4.1: **QL1 Quantile Distribution.**



4.4 Baseline regression and prediction model

Next, we present the main results of the observed sample and its augmentation method through a prediction model of the quality measures. First of all, based on the quantile prediction of QL1 in Figure 4.1, we can infer that its values are more scattered in the 1st quantile, rather than the other three. Thus, low performing countries are described by a greater variation in their test scores, compared to high performing countries. This result can also be observed at the 4th quantile, yet at a lower intensity. Moreover, we expect that Labor-Force quality is positively related with high average growth, since a well-educated population can be more productive. This is depicted at a first glance in Figure 4.2, in which the quadratic prediction of the 2 variables results in a positive slope.

Table 4.5 incorporates the major cross-country regressions of growth on human capital and several other variables, with the application of robust standard errors in the cases of detected heteroskedasticity. First of all, the initial income has a negative and statistically significant coefficient at 1% for all the cases, which means the Inada conditions are in place, since high income is related with low growth rates and vice versa. Second, the coefficient of the quantity of schooling is positive and significant when the population growth rate or the quality measures are not included in the model (column (1)), while it becomes insignificant otherwise. Considering the lower adjusted R-squared in the columns (4)-(6), adding POPG results in a slightly worsened specification. As for the quality measures QL1 and QL2, it is clear there is no major difference in their impact on growth when the population growth is taken into account, given the virtually same coefficients[3]. Most importantly, the effect of both of the Labor-Force quality measures on growth is consequently positive and statistically significant at 1% confidence level. Table A.2 in the Appendix section shows a comparison of the coefficients yielded in this paper and the ones H-K concluded in. Although the Labor-Force quality measures coefficients are quite close both in this research and in H-K, the coefficient of the initial income in 1960 is almost ten times greater in absolute value in comparison with the income in 1990. This result could be attributed to the fact that the majority of the countries in the respective samples were growing much faster in the 1960-1990 period, rather than the 1990-2019, given the significantly higher incomes of the westernized countries in the most recent years. Nevertheless, the coefficients are negative and statistically significant at 1% level of confidence in both of the cases.

In order to expand the initial sample of countries, we use a cross-country prediction model for the quality measures in Table 4.6 based on the methodology of H-K. In columns (1)-(3) and (4)-(6) we use different school resource variables to estimate the values of QL1 and QL2 respectively. The primary school enrollment rate seems to play a major role in determining the performance of students, since it is consequently significant, regardless of the school resource included. Other types of enrollment variables were also used but the one selected in this table resulted in the highest adjusted R-squared. Most notably, the quantity of schooling affects student performance, thus the different levels of education of parents determine the variation in the test scores of countries, in accordance with Table 4.4. The population size is also crucial to student performance, while it is related negatively with test scores. As for the resource variables, they either have the theoretically wrong sign in their coefficient (current expenditure and total government expenditure) or they are statistically insignificant (current public expenditure and pupil to teacher ratio). Other school resources, such as total government expenditure per student to GDP per capita, current public expenditure in primary and secondary schools, and pupil to teacher ratio in secondary schools, were also added to the model, giving similar results. Referring to the school resources coefficients, H-K found similar results. Notably, regional dummies were added in every regression as a treatment method (d_AS, d_AF, d_LA). Considering the adjusted R-squared, the selected specifications for the prediction of the quality measures were the ones including the total government educational expenditure to GDP (columns (3) and (6)).

[3] Of course the coefficients of the two measures are not exactly the same, given that we only keep the first three decimals in the entirety of the regressions.

Figure 4.2: **QL1 - GROWTH Quadratic Prediction**

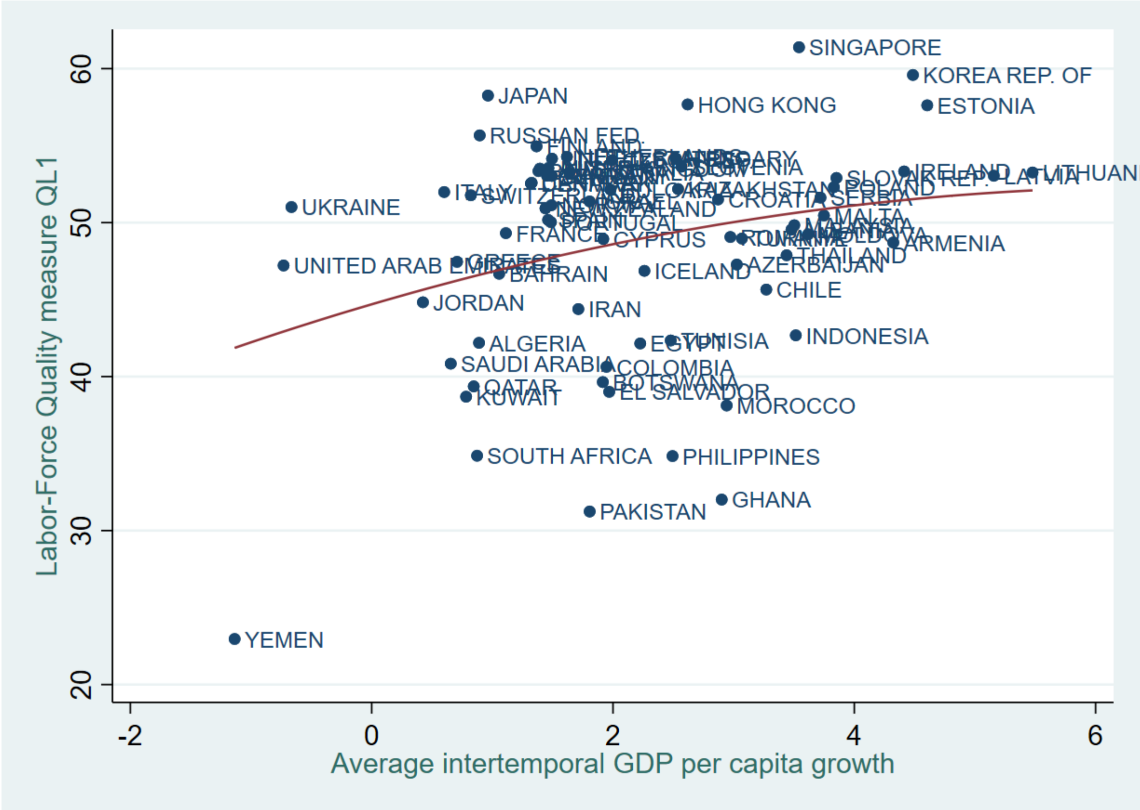


Table 4.5: **Baseline Growth Regression (1990-2019).**

(Dependent variable: Average annual growth rate of GDP per capita in constant 2015 $US (x100) - 58 countries)						
Independent variables	(1)	(2)	(3)	(4)	(5)	(6)
Initial income in 1990 in 1000s of constant 2015 $US (I90)	-0.044*** (0.011)	-0.046*** (0.011)	-0.048*** (0.010)	-0.041*** (0.012)	-0.046*** (0.013)	-0.048*** (0.012)
Quantity of schooling (SCH)	0.192*** (0.095)	-0.004 (0.095)	-0.012 (0.096)	0.159 (0.110)	-0.001 (0.103)	-0.012 (0.103)
Annual population growth (POPG)				-0.099 (0.158)	0.013 (0.172)	0.001 (0.149)
Labor-force quality QL1		0.084*** (0.029)			0.084*** (0.031)	
Labor-force quality QL2			0.090*** (0.030)			0.090*** (0.031)
Constant	0.893 (0.743)	-1.312 (1.132)	-1.555 (0.983)	1.257 (0.951)	-1.379 (1.441)	-1.558 (1.239)
Adjusted R-squared	0.20	0.28	0.30	0.19	0.27	0.29
H/S Robust standard errors	Yes	Yes	No	Yes	Yes	No

Notes:

1. The significance level of each coefficient is noted by the asterisks as such: 1%***, 5%** and 10%*.
2. The standard errors are shown in parentheses below each coefficient.
3. Robust standard errors were applied in the cases of heteroskedasticity.

Table 4.6: **Prediction Model of QL1 & QL2 (1990-2019).**

	Dependent: QL1			Dependent: QL2		
Independent variables	(1)	(2)	(3)	(4)	(5)	(6)
Net primary school enrollment rate (ENPRI_N)	32.958*** (9.934)	37.024*** (7.147)	38.398*** (7.276)	33.552*** (10.180)	38.394*** (7.429)	39.627*** (7.547)
Quantity of schooling (SCH)	1.484*** (0.317)	1.568*** (0.304)	1.533*** (0.248)	1.495*** (0.328)	1.586*** (0.320)	1.548*** (0.258)
Primary school pupil-teacher ratio (PTPRI)	-0.045 (0.167)			-0.043 (0.172)		
Current public expenditure on education as a % of total expenses in public institutions (CEXP)		-10.184 (11.869)		-12.913 (12.772)		
Total government expenditure on education/GDP (TEXP_GDP)			-106.007*** (36.942)			-124.948*** (38.319)
Annual population growth (POPG)	-1.272*** (0.424)	-1.273*** (0.432)	-1.024*** (0.402)	-1.040* (0.532)	-1.069** (0.498)	-0.757* (0.417)
Asian country = 1 (d_AS)	1.136 (1.473)	0.887 (1.646)	-0.559 (1.375)	0.956 (1.503)	0.691 (1.692)	-0.993 (1.427)
African country = 1 (d_AF)	-1.837 (2.498)	-2.910 (2.723)	-1.444 (1.813)	-2.240 (2.579)	-3.167 (2.738)	-1.686 (1.880)
Latin American country = 1 (d_LA)	-2.432 (2.115)	-3.019** (1.258)	-4.200* (2.212)	-2.611 (2.191)	-3.181** (1.336)	-4.575** (2.294)
Constant	6.106 (12.911)	10.152 (11.586)	5.122 (6.350)	5.559 (13.248)	11.348 (12.159)	4.922 (6.587)
Adjusted R-squared	0.75	0.76	0.78	0.73	0.74	0.77
Number of countries	70	66	70	70	66	70
H/S robust standard errors	Yes	Yes	No	Yes	Yes	No

Notes:
1. The significance level of each coefficient is noted by the asterisks as such: 1%***, 5%** and 10%*.
2. The standard errors are shown in parentheses below each coefficient.
3. Robust standard errors were applied in the cases of heteroskedasticity.
4. The regressions with the TEXP_GDP resource variable (column (3) and (6)) were selected for the prediction of the quality measures QL1 and QL2 of the augmented sample.

4.5 Augmented regression

The augmentation of the quality measures leads to an increase of 63 observations, namely from 58 to 121 countries. The summary statistics in Table 4.7 show a relative decrease in the means of QL1, QL2, SCH, I90 and ENPRI_N, and a slight increase in POPG, compared to Table 4.1. The correlation matrix (Table 4.8) now shows a higher correlation coefficient between QL1 and QL2 (from 99.6 to 99.8), once again making them virtually the same. The high correlation between SCH and the quality measures still does not lead to multicollinearity, based on the Vector Inflation Factor test. The TEST dummy addresses the possible impact of the augmentation on growth, as it equals 1 for the countries of the initial/observed sample and 0 for the augmented ones, while TEST1 and TEST2 calculate the effect of the interaction between TEST and QL1 and QL2 respectively. Thus, they refer to the possible implications of the augmentation on the Labor-Force quality measures.

The results of the augmented regressions are presented in Table 4.9, in which there are many differences compared to the baseline regression in Table 4.5. Regarding, the impact of the initial income on growth is somewhat lower in absolute values, while the coefficients of the quality measures are much higher. The TEST dummy and its interactions with the quality measures (TEST1 and TEST2) are insignificant in every case in accordance with H-K, although it must be noted that their inclusion leads to multicollinearity, given their high correlation as shown in Table 4.8. Adding them separately to combat multicollinearity (not shown) still resulted in insignificant coefficients.

Table 4.7: **Summary Statistics of the Augmented Regression.**

Variable	Median	Mean	Standard Deviation	Minimum	Maximum	Observations
QL1	45.89	44.58	8.19	25.94	61.39	143
QL2	46.21	44.90	8.18	26.22	61.76	143
POPG (Population growth rate x100)	1.35	1.33	1.24	-1.11	6.28	143
GROWTH (GDP per capita growth x100)	1.81	2.15	1.76	-1.80	9.79	143
I90 (Initial income in 1990 in 1000s of constant 2015 $US)	3.36	9.67	14.19	0.01	70.06	125
SCH (Average adult schooling quantity in years)	8.18	7.96	2.83	2.13	12.89	135
PTPRI (Primary pupil-teacher ratio)	21.68	24.92	13.12	8.86	86.67	140
PTSEC (Secondary pupil-teacher ratio)	16.25	17.35	7.71	7.11	53.10	135
ENPRI_N (Primary school net enrollment rate x100)	92.17	89.52	9.70	57.41	99.68	139
ENSEC_N (Secondary school net enrollment rate x100)	78.96	69.95	23.51	10.38	99.66	131
CEXP (Current public education expenditure/ total expenditure in public institutions x100)	91.61	90.29	6.08	60.24	99.87	122
TEXP_GDP (Government expenditure on education/GDP x100)	4.26	4.40	1.58	1.44	10.89	140

Table 4.8: **Correlation Coefficients of the Augmented Regression Variables.**

(Dependent: GROWTH)

	QL1	QL2	POPG	I90	SCH	GROWTH	TEST	TEST1	TEST2
QL1	1								
QL2	0.9978	1							
POPG (Population growth rate x100)	-0.6112	-0.5806	1						
I90 (Initial income in 1990 in thousands of constant 2015 $US)	0.5346	0.5517	-0.1295	1					
SCH (Average adult schooling quantity in years)	0.8565	0.8481	-0.5715	0.5885	1				
GROWTH (GDP per capita growth x100)	0.2195	0.2164	-0.2679	-0.2059	0.0046	1			
TEST	0.4675	0.4644	-0.2759	-0.2759	0.4710	0.0247	1		
TEST1 (TEST x QL1)	0.5601	0.5577	-0.3313	-0.3313	0.5388	0.0315	0.9824	1	
TEST2 (TEST x QL2)	0.5600	0.5588	-0.3249	-0.3249	0.5383	0.0316	0.9822	0.9998	1

The most interesting part of this table is the coefficient of SCH, which is positive and significant at 10% at column (1), it becomes insignificant when the population growth rate is added, and finally it is significant at 1% and has a negative sign when the quality measures are included in the regression, visible in columns (3)-(8). Therefore, given the change in the sign of SCH when the quality measures are added, we can infer that in order for a nation to have a high growth, it must be that the high years of schooling be accompanied by high quality of schooling. For example, the population of a nation which is educated poorly (low QL1 and QL2) for many years (high SCH) will ultimately have lower growth rates, compared to another country with low Labor-Force quality and low average years of schooling. The results of this table largely differ from the similar table of H-K, who find lower coefficients in QL1 and QL2, and insignificance in SCH. Notably, H-K get a maximum of 80 countries in their augmented regression, while we get 121.

Table 4.9: **Augmented Growth Regression (1990-2019).**

(Dependent variable: Average annual growth rate of GDP per capita in constant 2017 $US (x100) - 134 countries

Independent variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Initial income in 1995 in 1000s of constant 2017 $US (I95)	-0.036*** (0.013)	-0.025*** (0.010)	-0.041*** (0.011)	-0.035*** (0.011)	-0.038*** (0.011)	-0.044*** (0.011)	-0.037*** (0.011)	-0.041*** (0.011)
Quantity of schooling (SCH)	0.112* (0.064)	-0.033 (0.084)	-0.299*** (0.107)	-0.331*** (0.111)	-0.316*** (0.105)	-0.275*** (0.104)	-0.322*** (0.110)	-0.291*** (0.102)
Annual population growth (POPG)		-0.498*** (0.169)		-0.245 (0.151)			-0.286* (0.151)	
Labor-force quality QL1			0.165*** (0.033)	0.149*** (0.032)	0.184*** (0.040)			
Labor-force quality QL2						0.161*** (0.033)	0.146*** (0.031)	0.178*** (0.040)
Assessment available = 1 (TEST)					2.133 (1.422)			1.944 (1.440)
Observed QL1 - TEST x QL1					-0.047 (0.033)			
Observed QL2 - TEST x QL2								-0.042 (0.033)
Constant	1.456*** (0.455)	3.172*** (0.825)	-2.580*** (0.854)	-1.356 (1.032)	-3.272*** (1.103)	-2.603*** (0.871)	-1.241 (1.039)	-3.224*** (1.138)
Adjusted R-squared	0.05	0.11	0.24	0.25	0.24	0.24	0.25	0.23
H/S robust standard errors	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes:

1. The significance level of each coefficient is noted by the asterisks as such: 1%***, 5%** and 10%*.
2. The standard errors are shown in parentheses below each coefficient.
3. Robust standard errors were applied in the cases of heteroskedasticity.
4. Adding TEST with TEST1 or TEST2 resulted in multicollinearity (columns (5) and (8)) due to the high correlation between these specific variables. Yet, they were kept in the regression in accordance with Hanushek and Kimko (2000). Adding them separately resulted in insignificant coefficients as well.
5. Countries with a score lower than 25 were excluded in order to avoid extreme observations.

4.6 Wage Efficiency

Moving on, we attempt to estimate the impact of teacher wages on student achievement by adopting the prediction model of Table 4.6 and using a variable of teacher salaries as a school resource, instead of pupil to teacher ratio, current public educational expenditure or the total government expenditure to GDP. Specifically, we use data from 34 OECD countries to calculate the intertemporal average of the statutory teacher salaries, using all available information for the time-range of 2000-2020[4]. We convert salaries of local

[4] A ”statutory salary” includes both the annual wage and the bonuses.

currencies to $US by using the Purchasing Power Parities for each available year. The summary statistics and the correlation matrix of this set of countries presented in Table 4.10 and Table 4.11 refer to the values of the augmented sample[5]. An interesting point in the summary statistics is the great difference between the minimum and maximum values of the salaries, which, given the relatively small number of countries, can be seen as extremes. Nevertheless, as presented in Table 4.12 they do not lead to anomalies. As for the correlation matrix, there does not seem to be any high correlation coefficient, since the correlations of the quality measures and the schooling quantity are less than 0.70, in contrast to the previous correlation matrices (Table 4.2 and Table 4.8).

Table 4.10: **Summary Statistics of the Wage Efficiency Regression (Augmented sample 1990-2019).**

Variable	Median	Mean	Standard Deviation	Minimum	Maximum	Observations
QL1	52.90	51.59	4.21	40.63	59.59	35
QL2	53.10	51.91	4.24	40.73	59.92	35
POPG (Population growth rate x100)	0.52	0.62	0.76	-1.11	2.32	35
SCH (Average years of adult schooling quantity in years)	11.12	10.45	1.71	6.03	12.89	35
ENPRI_N (Primary school net enrollment rate x100)	96.39	95.19	3.86	84.42	99.62	34
TS (Statutory teacher salary in primary education in 1000s of $US, PPPs)	41.30	42.62	18.78	7.60	101.01	35

Table 4.11: **Correlation Coefficients of the Wage Efficiency Regression Variables (Augmented sample 1990-2019).**

(Dependent: QL1 & QL2)						
	QL1	QL2	POPG	SCH	ENPRI_N	TS
QL1	1					
QL2	0.9980	1				
POPG (Average growth rate x100)	-0.4766	-0.4623	1			
SCH (Average adult schooling quantity in years)	0.6969	0.6931	-0.2032	1		
ENPRI_N (Primary school net enrollment rate)	0.0279	0.0310	0.1395	-0.0123	1	
TS (Statutory teacher salary in primary education in 1000s of $US, PPPs)	0.1632	0.1964	0.4488	0.2248	0.2027	1

[5] No assessment was available for Costa Rica, Luxembourg and Mexico, so their values for QL1 and QL2 were predicted. The summary statistics and the correlation matrix of the observed sample are not shown.

The main results of the wage efficiency regressions are shown in a set of cross-country regressions in Table 4.12. In comparison to the prediction model in Table 4.6, we can initially observe that the enrollment rate is irrelevant to student achievement in this case, most likely due to its low variation between the OECD countries. Moreover, the regional dummies in this sample generally have a significant coefficient, which nonetheless does not seem to affect the impact of the other independent variables. Other major determinants of student performance is the education of parents and the population growth, similarly to Table 4.6. The most interesting part here is the consequent significance and the positive sign of the teacher salaries' variable TS. Namely, if we take into account the results in column (4), a standard deviation increment of 18.78 thousands of $US in the average salary of a country results in 1.13 points higher QL1. Therefore, the teacher salaries can be considered as an important school resource, at least for the OECD countries. Notably, there are no significant differences in the coefficients of the observed and augmented samples, especially in the cases which include the teacher salaries (columns (2), (4), (6) and (8)).

Table 4.12: **Wage Efficiency Regression (Observed and Augmented sample 1990-2019).**

	Dependent variable: QL1				Dependent variable: QL2			
Independent variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Primary school net enrollment rate (ENPRI_N)	-0.794 (9.465)	-4.181 (8.912)	-0.645 (9.207)	-2.943 (8.362)	-0.954 (9.721)	-4.816 (8.927)	-0.887 (9.546)	-3.509 (8.420)
Quantity of Schooling (SCH)	1.122*** (0.253)	1.080*** (0.236)	1.115*** (0.252)	1.073*** (0.228)	1.094*** (0.260)	1.047*** (0.236)	1.088*** (0.261)	1.040*** (0.229)
Statutory teacher salaries in primary education in 1000s of $US, PPPs (TS)		0.058*** (0.026)		0.060*** (0.022)		0.066** (0.026)		0.068*** (0.022)
Annual population growth rate (POPG)	-2.102*** (0.610)	-2.970*** (0.686)	-1.842*** (0.565)	-2.977*** (0.661)	-1.999*** (0.626)	-2.988*** (0.687)	-1.703*** (0.586)	-2.999*** (0.666)
Asian country = 1 (d_AS)	4.574*** (1.432)	5.504*** (1.392)	4.177*** (1.389)	5.464*** (1.342)	4.418*** (1.470)	5.477*** (1.394)	3.969*** (1.440)	5.438*** (1.352)
Latin American country = 1 (d_LA)	-3.994** (1.832)	-2.904 (1.768)	-4.361*** (1.522)	-2.684* (1.508)	-4.264** (1.882)	-3.021 (1.771)	-4.728*** (1.578)	-2.815* (1.519)
Constant	41.762*** (9.648)	43.360*** (8.982)	41.688*** (9.430)	42.194*** (8.523)	42.499*** (9.909)	44.322*** (8.997)	42.504*** (9.778)	43.082*** (8.581)
Adjusted R-squared	0.69	0.73	0.77	0.81	0.67	0.73	0.76	0.81
Number of countries	31	31	34	34	31	31	34	34
Observed or Augmented	OBS	OBS	AUG	AUG	OBS	OBS	AUG	AUG
H/S robust standard errors	No	No	No	No	No	No	No	No

Notes:
1. The significance level of each coefficient is noted by the asterisks as such: 1%***, 5%** and 10%*.
2. The standard errors are shown in parentheses below each coefficient.
3. Since there is no available data of teacher salaries for any African country, the dummy d_AF was omitted.

4.7 Exclusion of East Asian countries

Continuing, we test the robustness of the baseline and the augmented regression by gradually excluding East and South East Asian countries, some which are considered to have a high student performance, and others being newly industrialized, thus they have high rates of growth. The theoretical aspect behind this test is that certain countries could be driving the results of the whole sample, due to their ”extreme” observations. Before moving on to the results, we should note that H-K examined the period of 1960-1990, in which the

East Asian rapidly growing countries were Hong Kong, Japan, Singapore, South Korea and Taiwan. Based on our sample these countries are considered as high income nations, according to the World Bank classification. Unfortunately, data for Taiwan is largely unavailable for the period we examine, so for the observed group, we only include the first four.

Table 4.13 presents this robustness check. Columns (1) and (4) present the baseline and the augmented regressions without exclusions, and while progressing the test, we gradually exclude the high income, then the high performing in student achievement and finally the newly industrialized countries. Looking at the observed group estimations (columns (1)-(3)), the QL1 coefficient seems to be less significant as we exclude more countries. Nevertheless, it remains relatively stable, positive and significant in every case. As for the augmented group (columns (4)-(8)), the exclusion still results in largely unaffected coefficients, both in their significance and in their impact on growth. Therefore, the observed and augmented estimations are robust in this aspect.

Table 4.13: **The Importance of East and Southeast Asian Countries (1990-2019).**

Dependent variable: Average annual growth rate of GDP per capita in constant 2015 $US (x100)

	Observed Sample			Augmented Sample			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Independent variables	Full sample	Excluding High income and High performing	Excluding NICs	Full sample	Excluding High income	Excluding High performing	Excluding NICs
Initial income in 1990 in 1000s of constant 2015 $US (I90)	-0.046*** (0.011)	-0.046*** (0.011)	-0.043*** (0.011)	-0.041*** (0.011)	-0.037*** (0.010)	-0.034*** (0.011)	-0.032*** (0.011)
Quantity of schooling (SCH)	-0.004 (0.095)	0.013 (0.099)	0.033 (0.109)	-0.299*** (0.107)	-0.320*** (0.116)	-0.254*** (0.092)	-0.271*** (0.096)
Labor-Force quality QL1	0.084*** (0.029)	0.079** (0.035)	0.076* (0.039)	0.165*** (0.033)	0.171*** (0.038)	0.146*** (0.031)	0.150*** (0.032)
Constant	-1.312 (1.132)	-1.235 (1.271)	-1.403 (1.344)	-2.580*** (0.854)	-2.694*** (0.983)	-2.203*** (0.848)	-2.322*** (0.882)
Adjusted R-squared	0.28	0.27	0.26	0.24	0.22	0.20	0.19
Number of countries	58	55	51	121	116	114	110
H/S robust standard errors	Yes	Yes	Yes	Yes	Yes	No	No

Notes:

1. The significance level of each coefficient is noted by the asterisks as such: 1%***, 5%** and 10%*.
2. The standard errors are shown in parentheses below each coefficient.
3. Robust standard errors were applied in the cases of heteroskedasticity.
4. The high income and high performing countries in the observed sample (column (2)) coincide: Hong Kong, Japan, Korea and Singapore.
5. The "High performing" label refers to students' performance in PISA international assessments, given their countries' GDP per capita. Source: *World Bank Blogs - Which region in the world has the smartest kids? According to OECD, it's East Asia.*
6.Column (3) excludes the column (2) countries plus Indonesia, Malaysia, Philippines and Thailand.
7. Column (5) excludes Hong Kong, Japan, Korea, Singapore (observed) and Brunei (augmented).
8.Column (6) excludes the column (5) countries plus China and Vietnam (augmented).
9. Column (7) excludes the column (6) countries plus Indonesia, Malaysia, Philippines and Thailand (observed).

4.8 Comparison of alternative specifications

We also provide a set of alternative specifications on the explanation of growth differences between countries, as well as another way to test the robustness of the quality measures as adequate explanatory variables. This is achieved by directly adding school resource variables as independent in the cross-country growth regressions. Table 4.14 presents these results. We test different specifications, beginning from the simple augmented regression without any quality measures or resources in column (1), and continuing by adding school resources (columns (2)-(3)) and Labor-Force quality measures (columns (4)-(5)). Finally, we include both quality and resources in columns (6) and (7). Interestingly, the pupil to teacher ratio in primary school is significant with the theoretically correct sign, while the ratio in secondary school is also significant, yet positive. As for the total government expenditure on education to GDP, it seems it does not affect growth directly, although it affects the student performance as shown in the prediction model (Table 4.6). Finally, if all variables are included as presented in columns (6) and (7), it seems that, compared to (4) and (5), the coefficients of schooling quantity and quality are slightly lower. Nonetheless, they are still significant with the correct sign. Consequently, school resources can directly affect growth, even in the presence of the parental education SCH and the Labor-Force quality measures QL1 and QL2.

Table 4.14: **Comparison of Alternative Human Capital Quality Measures (1990-2019).**

(Dependent variable: Average annual growth rate of GDP per capita in constant 2015 $US (x100))

	Baseline	Adding school inputs		Adding quality measures		Combined input and quality	
Independent variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Initial income in 1990 in 1000s of constant 2015 $US (I90)	-0.036*** (0.013)	-0.039*** (0.012)	-0.036*** (0.010)	-0.041*** (0.011)	-0.044*** (0.011)	-0.042*** (0.011)	-0.044*** (0.012)
Quantity of schooling (SCH)	0.112* (0.064)	-0.045 (0.083)	0.135** (0.064)	-0.299*** (0.107)	-0.275*** (0.104)	-0.328*** (0.106)	-0.320*** (0.104)
Primary school pupil-teacher ratio (PTPRI)		-0.073*** (0.022)				-0.056*** (0.021)	-0.057*** (0.021)
Secondary school pupil-teacher ratio (PTSEC)		0.064* (0.035)				0.062** (0.032)	0.063** (0.032)
Total government expenditure on education/GDP (TEXP_GDP)			-12.985 (8.993)			-5.174 (9.141)	-2.739 (9.354)
Labor-Force quality QL1				0.165*** (0.033)		0.143*** (0.034)	
Labor-Force quality QL2					0.161*** (0.033)		0.142*** (0.034)
Constant	1.456*** (0.455)	3.474*** (0.999)	1.833*** (0.655)	-2.580*** (0.854)	-2.603*** (0.871)	-0.815 (1.539)	-0.964 (1.566)
Adjusted R-squared	0.05	0.12	0.06	0.24	0.24	0.25	0.25
Number of countries	121	116	121	121	121	116	116
H/S robust standard errors	No	No	Yes	Yes	Yes	No	No

Notes:
1. The significance level of each coefficient is noted by the asterisks as such: 1%***, 5%** and 10%*.
2. The standard errors are shown in parentheses below each coefficient.
3. Robust standard errors were applied in the cases of heteroskedasticity.

4.9 Panel regression of growth

In the final part of the results section, we attempt to transfer the cross-country model of growth to a panel regression. To achieve this we use all available data on international achievement, schooling quantity, growth and other variables from 1960 through 2015. Due to the low availability of schooling quantity and income data in the related datasets, we ultimately get a total of 8 different assessment years from 1985 to 2015, regarding a maximum of 42 countries. The next challenge arises in the transformation of the included variables, especially the initial income and the Labor-Force quality QL1. As schooling quantity and population growth simply refer to the values collected from our sources, the variables of schooling quality QL1 and initial income I20 have a different story[6]. The former is calculated as the yearly weighted average of a country's test scores in several *TIMSS*, *IEA* and *IAEP* assessments, normalized to a mean of 50, each weight being the normalized inverse standard error of every score. Thus, it is constructed by using the same procedure, but instead of pooling all scores into a single observation, we create separate values for each year. To avoid any biased outcome, we only include the countries that have participated in at least 3 different assessment years. As for the initial income, we simply collect the values of the GDP per capita in constant 2015 $US of every country in the year t-20[7]. Other lags ranging from t up to t-30 were also tested, but it turns out that the one included in the following regression was the best at explaining the differences in growth, given the R-squared values.

The panel regressions of growth are presented in Table 4.15. Visibly enough, there are no fixed effects applied in the first two columns, while (3)-(5) incorporate the possible time and country heterogeneity. The last column shows a 2-Stage Least Squares regression, which uses the first lags of the Labor-Force quality QL1 and schooling quantity SCH to account for possible endogeneity. The first noticeable difference from the cross-country model is the higher in absolute values coefficient of the initial income variable I20. However, its effect is insignificant in the cases which attribute the country fixed effects in columns (3) and (5). Therefore, there consist other unobserved country characteristics, which directly affect growth, along with the Labor-Force quality and the population growth rate. The Labor-Force quality coefficient QL1 seems to be consequently positive and significant at a 10% or 5% level of confidence, while it increases in size when country heterogeneity is taken into account. As for the other variables, the schooling quantity SCH becomes insignificant in the cases, which include QL1, while the population growth rate is negative and significant in every regression. Additionally, a Hausman test was applied in comparison of specifications (2) and (3), to detect if differences in countries' characteristics are random or systematic. The result of the test indicated a preference for random over fixed effects. Finally, the first lags of QL1 and SCH are used as an instrumental variable in the 2SLS regression in column (6), and it seems that they do not affect the growth rates, meaning human capital endogeneity does not have a strong impact on growth. Specifically, the initial income I20 and the population growth POPG impact the GDP per capita growth negatively, while QL1 and SCH are insignificant. Generally, some of the included variables in the panel regression affect growth directly, while the impact of others is disputed.

[6] As aforementioned, schooling quantity was collected from the *GCDL*, and the population growth rates emanated from the *WDI*.

[7] Although some student test scores and schooling quantity data in 1970 were also available, they could not be incorporated, since the earliest income data, provided by the *WDI*, begin in 1960.

Table 4.15: **Panel Regression of Annual Growth Rate with Labor-Force Quality (1985-2015).**

(Dependent variable: Annual growth rate of GDP per capita in constant 2015 $US (x100))						
	GLS regression					2SLS regression with instrumental variables
Independent variables	(1)	(2)	(3)	(4)	(5)	(6)
GDP per capita in year **t-20** in 1000s of constant 2015 $US (I20)	-0.104*** (0.022)	-0.091*** (0.025)	-0.041 (0.068)	-0.090*** (0.025)	-0.033 (0.123)	-0.061** (0.028)
Schooling quantity in year **t** (SCH)	0.296*** (0.108)	0.079 (0.147)	-0.260 (0.251)	0.098 (0.150)	0.250 (0.316)	-0.034 (0.166)
Annual population growth rate in year **t** (POPG)	-0.618*** (0.173)	-0.658*** (0.171)	-0.730*** (0.220)	-0.695*** (0.156)	-0.749*** (0.180)	-0.779*** (0.171)
Labor-Force quality QL1 in year **t**		0.102** (0.046)	0.240** (0.105)	0.086* (0.047)	0.198* (0.112)	0.001 (0.054)
Constant	2.110*** (0.773)	-0.862 (2.393)	-5.040 (6.100)	-1.078 (2.620)	-9.871 (6.900)	5.181*** (2.208)
R-squared	0.12	0.15	0.41	0.18	0.44	0.18
Fixed effects application	None (RE)	None (RE)	FE	TFE	FE & TFE	None (RE)
Number of observations	307	200	200	200	200	127
Number of countries	42	42	42	42	42	42

Notes:
1. The significance level of each coefficient is noted by the asterisks as such: 1%***, 5%** and 10%*.
2. The standard errors are shown in parentheses below each coefficient.
3. The regression was conducted in the frameworks of random effects (RE), cross-country fixed effects (FE), time fixed effects (TFE) and in a regression of instrumental variables (IV regression).
4. The performed Hausman specification test (not shown) indicated a preference of Random Effects over Fixed Effects.

5. Conclusions

5.1 Summary of Thesis achievements

This research has provided evidence on the importance of human capital quality on the growth of nations, as well as the forces driving the performance of students. Specifically, it seems there consists a positive relationship between growth and student achievement, both in cross-sectional (Table 4.5) and in panel analysis (Table 4.15), while the education of parents is insignificant in the presence of the schooling quality, except for the case of the augmentation of the sample (Table 4.9). Regarding, the education of parents has to be of high quality, for a country to have high growth. Testing the robustness of these specifications by excluding several East and South East Asian countries, the results are mostly unchanged both in their impact and their significance. Comparing the effect of these human capital measures on growth to the impact of other school resources (Table 4.13) yields consequently significant coefficients for the former, while the results for the latter are less clear. As for the differences in achievement, they are mostly attributed to variation in net primary school enrollment, parental education level and population growth rates as presented in Table 4.4 and Table 4.6, while other school resources have a low impact in the presence of the aforementioned variables. An exception might arise in the case of the statutory teacher salaries (Table 4.12), which seem to affect achievement positively and significantly, yet, due to the low sample of countries in this case, these outcomes should be viewed with caution. Furthermore, the results drawn by the panel regressions of growth in Table 4.15 are less conclusive. The human capital measures of schooling quantity and quality seem to interact in the same manner as in the cross-country case both in significance and in signs. However, the quality impact increases rapidly when cross-sectional heterogeneity is taken into account, which means there are other unobserved country characteristics affecting the growth rates.

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Appendix

Table A.1: **Sources of this research in comparison to Hanushek and Kimko (2000).**

	This research		Hanushek and Kimko (2000)	
Variables	Source	Time range	Source	Time range
QL1	TIMSS, IEA, IAEP	1985-2019	IEA, IAEP	1964-1991
QL2	TIMSS, NAEP	1995-2019	IEA, IAEP, NAEP	1964-1991
Growth of GDP per capita	World Bank	1985-2019	Unesco statistical yearbook (various years)	1960-1990
Population growth	World Bank	1985-2019	Unesco statistical yearbook (various years)	1960-1990
Schooling quantity	Global Change Data Lab	1985-2017	Barro-Lee (1993)	1960-1985
Initial GDP per capita	World Bank	1965-1995	Unesco statistical yearbook	1960
School enrollment (primary and secondary, net and gross %)	World Bank	1990-2019	Unesco statistical yearbook (various years)	1960-1990
Total government expenditure on education per student to GDP per capita	World Bank	1990-2019	Unesco statistical yearbook (various years)	1960-1990
Current educational expenditure*	World Bank	1990-2019	Unesco statistical yearbook (various years)	1960-1990
Pupil-teacher ratio (primary and secondary school)	World Bank	1990-2019	Unesco statistical yearbook (various years)	1960-1990
Statutory teacher salaries**	OECD STAT	2000-2019	-	-

Notes:

*While Hanushek and Kimko (2000) use the variables of "Current public expenditure per student" and "Recurring government expenditure to GDP", we use a different one instead of them, named "Current education expenditure in public institutions as a percentage of total expenditure" due to the unavailability of modern data of nominal current public expenditure. Although they are not the same variables, they both represent the role of the government in the essential expenditures of the educational institutions.

**The wage efficiency framework is not included in Hanushek and Kimko (2000).

Table A.2: **Coefficients of the baseline regression in this research in comparison to Hanushek and Kimko (2000).**

Variables	This research		Hanushek and Kimko (2000)	
Growth of GDP per capita	**Dependent**		**Dependent**	
Initial GDP per capita in 1000s of $US	-0.046*** (0.013)	-0.048*** (0.012)	-0.481*** (0.093)	-0.517*** (0.112)
Schooling quantity	-0.001 (0.103)	-0.012 (0.103)	0.106 (0.119)	0.116 (0.139)
Population growth	-0.099 (0.158)	0.001 (0.149)	-0.038 (0.215)	-0.250 (0.211)
Labor-Force quality QL1	0.084*** (0.031)		0.133*** (0.024)	
Labor-Force quality QL2		0.090*** (0.031)		0.098*** (0.015)
Constant	-1.555 (0.983)	-1.558 (1.239)	-1.756 (1.346)	-0.151 (1.142)
R-squared	0.32	0.34	0.73	0.69

Notes:
1. The significance level of each coefficient is noted by the asterisks as such: 1%***, 5%** and 10%*.
2. The standard errors are shown in parentheses below each coefficient.
3. Robust standard errors were applied in the cases of heteroskedasticity.
4. In this research, we use the initial GDP per capita in 1990 (in 2015 $US), while Hanushek and Kimko (2000) use the income in 1960 (in 1960 $US).