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PISA score as an inappropriate measure for growth? Empirical evidence from East Asia

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ABSTRACT

The topic of the research is whether better human capital, as determined by secondary school learning outcomes measured by PISA scores, promotes economic growth. The literature often uses the PISA results as a proxy for growth, while its use and impact on growth are not empirically proven. These questions are analyzed through two hypotheses. The first hypothesis (H1) states that in a worldwide sample of countries, GDP per capita growth between 2006 and 2019 was positively impacted by rising PISA results. The second hypothesis (H2) states that between 2006 and 2019, the rise in PISA scores in East Asia had a stronger influence on economic growth than in the rest of the world. The study examines 59 nations that have administered two PISA tests during the period of 2006–2019. The findings imply that there is generally no causal connection between PISA results and growth and the PISA results play no additional role in the development of East Asian nations. The results can be explained in two ways. The first is that human capital includes more than just skills. The second is that the data only covers a short period of time, which may limit the analysis of long-term patterns.

KEYWORDS

growth, PISA scores, cognitive skills

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1. INTRODUCTION

Countries have long set the goal of sustaining economic growth, which proved to be a popular topic in the economics literature. Since the 1950s, human capital has been an integral part of research on the positive impact of human capital on growth. This paper seeks to answer the question of how and individual's skills, being a key part of human capital, affect a country's growth.

Human capital can be measured in several ways, either through traditional approaches such as cost-based, income-based, or education-based approaches, where it can be divided into output-based and input-based. The education-based approach measures human capital by looking at indicators like literacy rates, enrollment rates, dropout rates, repetition rates, average years of schooling, and test scores. These indicators have a strong correlation with educational investment, but educational metrics are more like proxies than true representations of human capital (Le et al. 2003). The study focuses on the qualitative education-based approach and skills, based on the research of Barro and Lee (2001) and Hanushek and Kimko (2000).

We concentrate on test results, particularly the PISA results that measure cognitive capacities and educational outcomes. PISA views education as being only focused on promoting economic growth and competitiveness. Thus, it solely evaluates topics that are typically seen as crucial for enhancing competitiveness in the global economy driven by science and technology, such as reading, arithmetic, science, financial literacy, and problem-solving (Zhao 2020). However, the extent to which PISA scores affect growth has been less explored.

The literature has investigated how various test results affect growth and has consistently found strong positive relationships between them. Some of the researchers use secondary education data (Lee – Lee 1995; Cheung – Chan 2008), but it has been more common to use models that work with various tests from different age levels (Hanushek – Kimko 2000; Lee – Lee 1995; Barro 2001; Coulombe – Tremblay 2006; Hanushek – Woessmann 2008; Altinok 2007; Atherton et al. 2013). In this research, we primarily test PISA scores without using other tests scores. In general, we are answering the question whether PISA scores alone affect growth.

East Asia is becoming a more attractive research topic in the literature due to its strong differences from the rest of the world in terms of culture and education (Jerrim 2015; Ho 2001; Ho 2009; Schneider – Lee 1990), returns on education (McMahon 1998) and its excellent PISA results (Wang – Cheng 2022; World Bank 2018). It is interesting to consider that education may have also contributed more to growth in East Asia than in other regions. This is the reason that in the second part of the research, we test the claim that PISA scores' impact on growth is different if a country is in the East Asia (EA) region or not.

The main research question of the paper is "Does improved human capital, as measured by secondary school learning outcomes, enhance economic growth?". We have broken down this research question into two hypotheses. The first hypothesis is that the increase in PISA scores will have a positive effect on GDP per capita growth in a global sample between 2006 and 2019 (H1). The second hypothesis is that the increase in PISA scores in East Asia has a greater impact on growth than in the rest of the countries between 2006 and 2019 (H2).

The research contributes to literature in two ways. First, the literature lacks a panel model that only examines the relationship between PISA scores and growth, while policy makers often use PISA scores as a relevant measure for economic growth and the current state of excellence

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of a country, as well as a key performance indicator in everyday decision making. A second contribution is to examine precisely how East Asian countries' PISA scores affect growth in the region. We investigate the assertion that the impact of a country's PISA scores on growth depend on whether it is a member of the East Asian region or not.

The study used a sample of 59 countries from 2006 to 2019 that includes nations that have administered the PISA test at least twice. In the second panel regression, we selected a narrower sample of 50 countries due to the lagged effect, using dependent and control variable data from 2006 to 2019, with PISA scores collected from 2006 to 2012. The independent variable is the PISA score, the dependent variable the GDP per capita, the control variables are population change, economic openness, life expectancy, investment, and government expenditure.

In the model, we used data from Barro and Lee's (2013) database, which measures the average years of primary schooling above 15, to calculate the average time of entry into the labor market of PISA test takers, which implies that PISA scores influence economic growth six years later. We also tested the interaction of the PISA scores and the East Asian dummy. We used fixed effect panel models with year fixed effects.

Overall, PISA scores do not significantly affect growth, while the control variables, population change, life expectancy, investment, and governmental expenditure do. The first hypothesis – that an increase in PISA scores will have a positive impact on the growth of the global sample's GDP per capita between 2006 and 2019 – is rejected. We also rejected the second hypothesis, which contends that between 2006 and 2019, East Asia's PISA results had a higher influence on growth than those of the rest of the world. This is evidence that the PISA results cannot necessarily be clearly made the pillar of growth and the center of various policies based on it.

The paper is structured as follows. Section 2 contains the literature review, where measurement issues, the relationship between human capital and growth, and cultural differences related to education in East Asia are presented. In Section 3, we review the theory and define the exact hypotheses. Section 4 provides the data and descriptive statistics and gives the methodological overview. Section 5 and Section 6 contain the results and the conclusion with the final evaluation.

2. LITERATURE REVIEW

When forming daily policy, decision-makers should keep in mind that educational development is viewed as one of the pillars of the modern state. The importance of fundamental education for the development of the economy and of people has been largely acknowledged by both policy research and policy makers (Yan 2019).

Researchers examining economic growth in the 1950s discovered that the majority of growth remained unexplained when only the traditional production factors of labor, land, and capital were considered as independent variables (Solow 1956). Technological progress was previously thought to be the source of the "residual unexplained value," but subsequently it became clear that human capital, and hence education, needed to be added to the standard definition of capital (Mankiw et al. 1992). Thus, factors that account for the increase in schooling were included in the analysis of economic growth because the improvement in work quality was partly attributed to this increase in education (Goczek et al. 2021).

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2.1. Measurement issues

Human capital can be measured in many ways. Based on the literature, it can be divided into two major groups: the traditional approaches like cost-based, income-based, and education-based approach, where the education-based approach may be output-based and input-based (Le et al. 2003).

The cost-based approach works on adding up the expenditures incurred for individuals' human capital to measure the stock of human capital indirectly (Kwon 2009). The approach has several restrictions. For a cost-based calculation of human capital to be helpful, the components of the production of that capital and its costs must first be clearly specified. Second, cost-based estimations of the human capital stock heavily depend on the depreciation rate (Le et al. 2003).

The income-based approach focuses on the returns that a person receives from the job market after investing in education (Le et al. 2003). According to Mulligan and Sala-i-Martin (2000), total human capital is an accumulation of the quality adjustments made to each person's labor force participation. But the model depends critically on the assumption that salary variations represent production differences (Le et al. 2003). It rarely provides an accurate measurement, because other characteristics can have a greater impact on a person's income (Kwon 2009).

The education-based approach estimates human capital by examining metrics like literacy rates, enrollment rates, rate of dropout, repetition rates, average years of schooling, and test scores. These metrics are strongly tied to educational investment, but rather than being direct measurements of human capital, they are used as proxies for it (Le et al. 2003). The education-based approach can be divided into two parts, output-based and input-based. Earlier literature focused more on outputs (Mankiw et al. 1992; Romer 1990; Psacharopoulos – Arriagada 1986), such as the school enrollment rate, the literacy rate, and the years of schooling.

Since it is assumed that differences in human capital's quality are of a far lower impact than variations in its quantity, quality issues have been ignored in growth models. According to Hanushek and Kimko (2000), such an omission has proven to be a serious error. This led to the development of another branch of the educational-based approach, the input-based thinking.

Barro and Lee (1996) consider input metrics including the amount of money spent on public education per student, student-teacher ratios, teacher salaries, the duration of the school year, and output type quality measurements like repetition and dropout rates. Some metrics are essentially variations of the cost-based method to evaluating human capital (Le et al. 2003).

International exam scores for high school students and adults are among the additional high-quality human capital measurements introduced by Barro and Lee (2001). Test results, which evaluate educational outcomes and cognitive abilities, as well as provide international comparability, have appealing characteristics of an excellent human capital indicator.

2.2. Human capital and growth

Human capital affects growth in many ways, which are certainly interesting to review. One branch of human capital is education, which can have a positive effect on growth in several ways. Education may boost a workforce's human capital, which in turn improves labor productivity (Mankiw et al. 1992). Second, according to Romer (1990), education could enhance the

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economy's capacity for innovation. According to Nelson and Phelps (1966), education may help spread and transmit the knowledge required to use new technology.

Drawing on the work of Barro and Lee (2001) and Hanushek and Kimko (2000), this research focuses on skills and the qualitative educational-based approach. Within this research, we focus on test scores, especially on PISA scores, and their effect on growth.

The literature has examined the effect of different test scores on growth, all finding positive significant results between different tests results and growth (Hanushek – Kimko 2000; Lee – Lee 1995; Barro 2001; Coulombe – Tremblay 2006; Hanushek – Woessmann 2008; Altinok 2007; Atherton et al. 2013). Hanushek and Kimko (2000) investigated whether labor-force quality affects growth using cross-country regressions. The dependent variable was the growth rate of real GDP per worker between 1970 and 1985 in 31 countries and the independent variable was the average math and science score of six tests.

Several studies have focused on the impact of education on growth (Lee – Lee 1995; Barro 2001). Lee and Lee (1995) examined the growth rate of real GDP per worker between 1970 and 1985 in 17 countries. They found that science scores at the secondary school level, conducted by the IEA, have a positive effect on GDP per capita growth. Barro (2001) examined growth between 1965 and 1995, while interpreting education as the average score of math, science and reading tests. They used 10-year period panel regression with 3SLS lagged independent variable as instruments. Both studies found a positive relationship between the variables.

Hanushek and Woessmann (2008) investigated how cognitive skills affect growth with a cross-country regression. The dependent variable is the growth rate of real GDP per capita between 1960 and 2000 in 50 countries. The independent variable is the average score of several tests of math and science: the FIMS, the FISS, the FIRS, the SIMS, the SISS, the SIRS, the TIMSS, the TIMSS-Repeat, the PISA 2000/2002, the PIRLS, the TIMSS 2003; PISA 2003. The relationship is positive between them.

Altinok (2007) and Atherton et al. (2013) investigated how schooling quality affects growth. In Altinok's (2007) research, the dependent variable was the annual percentage growth in GDP per capita, averaged over 10 years, while the independent variable was the average math, science and reading test scores of seven international tests: TIMMS, PIRLS, PISA, SACMEQ, PASEC, LLCE and MLA. The OLS regression with country fixed effects and the GMM regression similarly found a positive connection at the country level. Atherton et al. (2013) looked at the effects of average math, science and reading scores on annual growth rate of GDP per capita. They used nine tests, the IEA Mathematics 1964; IEA Science 1970–71; IEA Second Mathematics 1980–82; IEA Second Science 1983–84; 1st IAEP 1988; 2nd IAEP 1990–91; TIMSS 1994–95; TIMSS 1999; TIMSS 2003. They also found a positive connection.

The PISA scores alone have been examined less. In Cheung and Chan's (2008) country level analysis, the authors use a cross sectional model looking at one period. Their research using 2003 PISA test values found a positive effect on PISA reading score and GDP per capita. This suggests that there is a significant gap in the literature using only PISA scores.

2.3. Education in East Asia

East Asia has long been a focus of attention in the literature. The macroeconomic returns to human capital in this region may differ from those in other parts of the world due to cultural differences in how the region values education. We test this theory separately in the analysis.

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The perception of East Asian education stands out for several reasons that make these countries different from other nations. First, the cultural variables such as the value placed on education, willingness to pay for after-school tutoring, establishing a good work attitude, and high expectations are frequently thought to be related to educational performance in East Asia (Jerrim 2015). Second, the families in East Asia put a strong value on academic success. High academic accomplishment is frequently seen as a way to pay tribute to one's ancestors and parents (Ho 2009). Children in East Asian civilizations typically have lofty educational goals because they study hard to live up to their parents' expectations rather than their own (Schneider – Lee 1990). Third, East Asian cultures have long held a firm conviction in the benefits of extensive testing. The pressure from internal and external exams, however, may cause students to worry a lot about their performance (Ho 2009). Fourth, another factor is that teachers are typically more demanding in East Asian societies (Ho 2001). Educators do not frequently award children with good grades or excellent marks. Also, they will look for the pupils' weak points to ensure there is always space for personal growth (Ho 2009). Fifth, in addition to these, it is worth looking at other variables linked to educational measures, such as time spent learning in school, extracurricular lessons, and the use of memorization and elaboration strategies (Ma et al. 2013).

To evaluate educational performance in the area, multiple transnational or national surveys are available. PISA is a transnational study (World Bank 2018), while the Chinese CEPS collects comprehensive information on household education spending, public funding for students, including free meals and textbooks, as well as a wide range of individual, family, class, and academic characteristics (Wang – Cheng 2022). In the analysis, we focus on PISA scores, as this is a generally comparable data, so differences between countries can be better identified.

The PISA or additional tests have been done throughout East Asia, including Beijing, Shanghai, Jiangsu, and Guangdong (B-S-J-Z China), Hong Kong, Indonesia, Macao, Malaysia, Singapore, Chinese Taipei, Thailand, and Viet Nam (OECD 2016). East Asian countries and administrative entities, particularly Japan, Korea, Hong Kong, Taiwan, Macao, and Singapore, have consistently ranked in the top tier in these global comparisons of math, reading and science achievement, dating back to the earliest international studies led by the International Education Association and the most recent TIMSS and PISA (Ho 2009; OECD 2016). The research also seeks to answer whether the increase in PISA scores in these countries has fostered growth.

3. THEORY AND RESEARCH QUESTION

The question arises next is how human capital and education should be measured. Skills are often referred to simply as the human capital stock of workers, which parallels the literature (Hanushek – Woessmann 2012; Hanushek – Woessmann 2020; Mankiw et al. 1992). One approach is to concentrate solely on the cognitive skills portion of human capital and use test-score indicators of reading, mathematics, and science proficiency. There are several possible benefits of using test scores because these contain all the skills from different sources like family, school and learning by doing (Hanushek – Woessmann 2012; Lucas 1988).

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Hanushek and Woessmann (2012) use an essentially simple growth model:

$$g = \gamma H + \beta X + \varepsilon \tag{1}$$

where g is a country's growth rate, H is a function of the skills of workers, X is other factors like economic institutions, initial levels of technology and income and, and other systematic factors. This approach does not show the exact channels through which the skills of workers affect economic growth, so this is explained in the next subsection (Fig. 1).

The first thing to look at what factors have an impact on the skills of workers. According to Lucas (1988), people gain skills from two primary sources: formal education and hands-on experience. In Hanushek's (2002) research, performance of a student is influenced by family inputs cumulative to time t, cumulative peer inputs, cumulative school inputs and innate ability. Hanushek and Woessmann (2012) further developed this theory into the following equation:

$$H = \lambda F + \varphi(q\ S) + \eta A + \alpha Z + \nu \tag{2}$$

where H is the skills, F is family inputs, qS is quantity and quality of inputs provided by schools, where S is the school attainment and q its quality and A is individual ability and Z is other factors, ν is the other factors.

One of the high-quality human capital assessments presented by Barro and Lee (2001) is the result of international exams taken by adults and high school students. The advantage is that the test results measure cognitive capacities and educational attainment. Also, a noteworthy advantage is that it gives international comparability have, highlighting enticing qualities of a superior human capital indicator.

The channels through which the skill of workers affects economic growth can be broken down into three categories: technology, innovation, and productivity (Romer 1990; Becker 1993; Lucas 1988; Mankiw et al. 1992).

First, education is able to spread and transmit the knowledge required to effectively analyze new information and apply newly developed technologies, what will encourage economic progress (Nelson – Phelps 1966). Also, the way a country's economy is divided among different sectors changes through time is another channel that education has an impact. Many industrialized, technology-driven nations have transitioned from an agricultural economy to a growing service and manufacturing sector that makes greater use of an educated labor force thanks to the effective analysis of new technologies (Timmer et al. 2019).

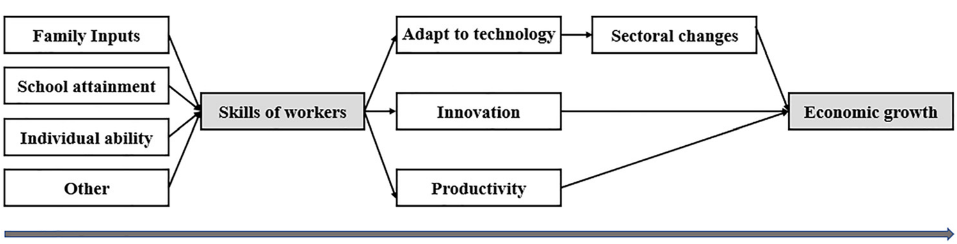

Fig. 1. Mechanisms between skills of workers and economic growth
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Second, according to the endogenous growth model, improvements in human capital can result in long-term differences in growth rates because a more educated workforce generates a larger flow of creative thoughts and innovative capacity that propel technological advancement at a faster rate (Romer 1990).

Third, the country's education system is viewed as the foundation for increasing workers' skill levels, which in turn will increase economic productivity (Lucas 1988; Mankiw et al. 1992). Additionally, it has been asserted that a workforce with greater education is more adaptable and, as a result, is better suited to deal with the swift changes in the economic environment (Becker 1993). This can elevate productivity as well.

4. DATA AND DESCRIPTIVES

4.1. Data

Data are analyzed between 2000 and 2019 for all countries with at least two PISA results. A total of 59 countries were included in the sample. After data selection, all countries with at least one PISA score were included in the sample.

4.1.1. Dependent variable. The GDP per capita variable is a good measure of a country's economic conditions because it filters out the variation in size between countries. The dependent variable is the change in GDP per capita, for which the GDP per capita variable must first be created. This is calculated from the Penn World Table Expenditure-side real GDP at chained PPPs in million 2017US$ and Population in millions (Feenstra et al. 2015):

$$GDP_{pc_{it}} = \frac{rgdpe_{it}}{pop_{it}}$$

As both are in millions, no further adjustment is necessary. The dependent variable is the change in the $GDP_{pc_{it}}$ variable between period t-1 and t.

4.1.2. Independent variables. The independent variable, which's primary impact on growth we are looking for, is the change in PISA scores, which measures the cognitive ability of the country's population of 15-year-old students. The PISA (Programme for International Student Assessment) is a strong international examination process of examining the students' academic performance. It has attracted high level of scientific and media attention since its establishment in 2000. The PISA test, which measures students' proficiency in math, reading and science, looks at students' ability to explore from what they have learned and apply that knowledge in everyday situations as well as to novel contexts (Jerrim 2015; Suprapto 2016). It is a continuing program that provides information about trends in students' knowledge and skill acquisition across countries and in various demographic subgroups within each country (Gurria 2016).

The data were collected by OECD. The variable was measured every 3 years between 2000 and 2018 in 37 OECD countries in 3 categories: mathematics, reading and science. It was measured by 32 other partner countries in addition to OECD countries, which makes it suitable for international comparison. An important point to note is that, as we are essentially looking at changes and dynamics, so we have only used data from countries that had at least two observations and has for every included year all the dependent, independent and control variables. In total, 50 countries were included.

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Only five East Asian countries were included in the sample due to lack of data. For these countries we create a dummy variable, which is later used to create a new interaction variable with the PISA score.

4.1.3. Control variables. The economic and educational systems must be examined simultaneously, but research can have skewed findings. This is because nations that are implementing policies to promote growth are also working on other ways to improve their educational systems too (Krueger – Lindahl 2001). This is also why it is important to use different control variables and different econometric methods to neutralize these effects.

Control variables are grouped into two factors: human resources and physical capital. The research develops a model to explain how much GDP per capita will change as a function of both the necessary and pertinent economic attributes and the level of education. The control variables are similarly constructed as in the work of Hanushek and Woessmann (2008) and Goczek et al. (2021).

The first group, human resources, is measured with life expectancy and population change. First, life expectancy ($life_{exp_{it}}$) is a World Bank aggregate variable, which is the number of years a newborn infant would live if current mortality trends at the time of their birth were to persist throughout their life. It is also known as life expectancy at birth.

Second, the population change is calculated from the PWT table population variable:

$$pop_{change_{it}} = \frac{pop_{it}}{pop_{it-1}} - 1$$

Physical capital has been measured by three variables: level of investment, government expenditures and the openness of the economy. Government expenditure ($govexp_{it}$) is a variable collected and measured by the IMF that looks at expenditure as a percentage of GDP. The level of investment ($investment_{it}$) is from the PWT table and looks at the share of gross capital formation at current PPPs in GDP. The openness of the economy ($openness_{it}$) is measured by the World Bank and OECD national accounts data as trade (the sum of exports and imports of goods and services) as a share of GDP.

4.2. Models

We used panel regression to simultaneously examine the effect of variables across time points. The unobserved geographical and temporal heterogeneity is taken into account by the fixed effects estimator. The impacts that are country and time-period specific, which encompass all the various country features, are handled as fixed effects. This estimation method produces an unbiased model by removing the country-specific, time-invariant characteristics from the explanatory variables (Brüderl – Ludwig 2015). This estimating method takes into account all the time-invariant traits of nations that have an impact on their economic performance in this setting. As a result, it serves as an effective safeguard against the biases caused by missing variables in these estimates. We additionally add the most pertinent controls using the data that is available to account for time-variant traits.

For groupwise heteroskedasticity in the residuals of a fixed effect regression model, we used the modified Wald statistic. According to the test, there is no groupwise heteroskedasticity in the regression, so therefore we modified the standard errors and variance to be robust.

When examining the normality of the data, it is important that the dependent variable is always normally distributed for the panel regression to work properly. The kurtosis of GDP per

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capita is 10.244 and the skewness is 1.924. The optimal kurtosis is 3, while the skewness is optimal between −0.5/+0.5 (Gawali 2021). Based on these criteria GDP per capita variables do not meet the normality requirement. To solve these, we generated a new variable, where we took the logarithm of the GDP per capita. The kurtosis of ln GDP per capita is 3.304 and the skewness is −0.417, which meets the normality criteria.

It is important to determine how the average time it takes for students who take the PISA test at 15 years of age to enter the labor market. This may be important because only after entering the labor market can they have an impact on GDP per capita. Barro and Lee's (2013) database, which measures the average years of primary schooling above 15, helps to calculate the lagged effect accurately. Data are collected for 2000, 2005 and 2010. Based on our own calculations, we estimated an average for the sample countries, which is nearly 5.43 years on average after 15 years. This implies that $GDP\_pc_{i,t}/GDP\_pc_{i,t-1}$ should link to a change in test scores between 5 and 6 years ago, so $PISA_{it}$ should be modified to $PISA_{it-6}$.

The equation for this is given below:

$$\Delta ln\left(GDP_{pc_{i,t}}/GDP_{pc_{i,t-1}}\right) = \beta_{1i} + \beta_2 * PISA_{it-6} + x'_{it} * \theta + \varepsilon_{it} \quad (3)$$

Where $\Delta GDP\_pc_{i,t}/GDP\_pc_{i,t-1}$ the GDP per capita growth of country i in year t, $PISA_{it}$ is a function for different PISA score changes (mathematics, reading, science) of country i in year t, β_{1i} is the individual-specific intercept of country i, x'_{it} is the vector of controls of country i in year t, β_2 and θ are the parameters of the model, and ε_{it} is the error term for country i in year t.

In parallel with the literature (Ho 2009; OECD 2016), the role of East Asia should be examined, so we also included the PISA scores and the interaction of the PISA scores and an East Asian dummy in a joint model to examine whether there is a change in the signs.

$$\Delta ln\left(GDP_{pc_{i,t}}/GDP_{pc_{i,t-1}}\right) = \beta_{1i} + \beta_2 * PISA_{it-6} + \beta_3 * PISA_{it-6} * D_{SEA} + x'_{it} * \theta + \varepsilon_{it} \quad (4)$$

Since the impact of PISA scores is examined over a 6-year time span, countries that started using the tests at the national level after 2013 do not include any scores for the PISA variables. we used a sample, with the criterion of having at least two score on the 2000, 2003, 2006, 2009 or 2012 tests so we can examine the dynamics in the period. In total, 50 countries met this criterion.

4.3. Summary statistics

The summary statistics show the main dependent, independent and control variables. The number of observations shows considerable variation. We present the summary statistics of the final regression. As only those with at least two PISA scores in a subject between 2000 and 2012 are included, the sample is significantly reduced. Over a total time span of 14 years, 50 countries were surveyed, for a total of 207 observations (Table 1).

Only periods that had observations for each variable in a period were included in the regression. Since several types of regressions were run, the number of outcome and control variables run alongside the tests is higher than the test numbers. The reason for this is that there were countries that did not have all types of tests. The cross-section of the 3 test regressions totals 207 observations, of which 202 were used for the reading regression and 187 for science and math.

Average GDP per capita is $37,127 with a lowest of $5,045 and a highest of $165,866. The average PISA scores ranged from 467 to 473, with a relatively similar spread. However, there is a significant difference in the minimum and maximum scores. The math score stands out as a

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Table 1. Summary statistics of the final regression

Variable	Obs	Mean	Std. dev.	Min	Max
$GDP_{pc\,it}$	207	37,127	21,305	5,045	165,866
$PISA_{reading\,it}$	202	472	47.853	312	556
$PISA_{science\,it}$	187	473	48.901	333	563
$PISA_{math\,it}$	187	467	54.16	292	548
$pop_{change\,it}$	207	0.007	0.009	−0.009	0.079
$openness_{it}$	207	99.094	69.336	22.106	430.569
$life_{exp\,it}$	207	78.804	3.552	66.728	84.934
$invest_{it}$	207	282,618	489,490	2,653	4,553,717
$govexp_{it}$	207	38.716	10.872	14.840	57.955

Notes: Sample between 2006–2019
Source: authors.

most volatile, with a minimum of 292 and a maximum of 548. The average population change in the countries is 7%, with a variance of 9%, which is moderate. Average life expectancy is 78.8 years, ranging from 67 to 85. Investment ranges from $2,653 to $4,553,717, which is a significant range. Government expenditure also covers a very wide range, from a minimum of 14.840% to a maximum of 57.955% of the GDP.

Figure 2 shows the PISA scores averaged over time, where a downward trend can be detected in every test. There are several reasons for this. First, countries experienced deteriorating PISA scores over the years, which may explain the declining linear trend. The second is that over time, more developing countries have joined, with their lower average scores dragging the statistics down. This may be evidenced by the fact that in 2003 there was a significant upward trend, which has been declining. This suggests that it is important to add an estimation that includes year fixed effects.

5. RESULTS

In the models run, the dependent variable was GDP per capita. By including country fixed effects, we do not need to run the regression with the changes, because it is equivalent with that. In the next section we run equations (3) and (4). In the model, we considered the period 2006 to 2019 for all countries in the sample (Table 2).

In Model 1–3, PISA scores, reading, science and math scores were not significant. This means that PISA scores measuring cognitive skills after entry into the labor market do not increase GDP per capita.

Several of the control variables are significant in the models. We can interpret a coefficient, if the explanatory variable increases by 1 unit or percent, the GDP per capita will change with the value of beta. First, an increase in population has a positive effect on growth for all scores in

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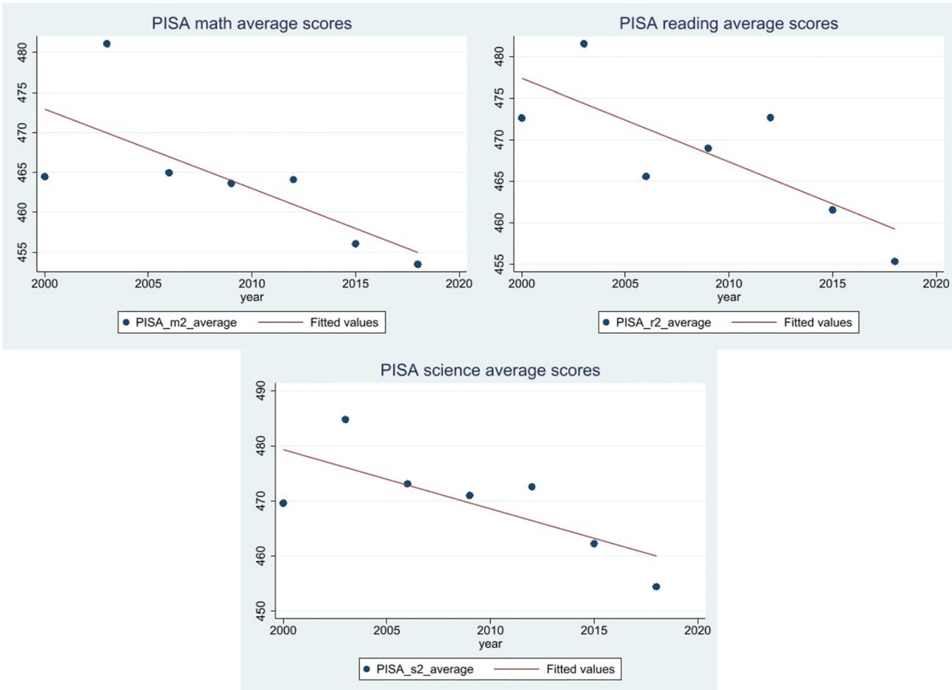

Fig. 2. Average PISA values between 2000 and 2012
Notes: Fitted values are calculated using a linear trend.
Source: authors.

the model. The higher this value, the higher growth is. An interesting result is that the second control variable, the openness of the economy, has no significant effect on growth.

Third, the increase in life expectancy has a positive effect on growth. The longer citizens live on average, the higher growth will be. Fourth, the greater the value of the investment, the greater the growth. Finally, an increase in government expenditure has a negative effect on GDP per capita growth (Table 3).

In the second set of modelling, we added the interaction of the East Asian dummy and the PISA scores to the models. The interpretation should consider whether significant or non-significant values were obtained for both the PISA score and its interaction, where two cases can be distinguished on this basis. In the first case, where the interaction is non-significant, we can simply say that the effect of PISA scores on growth is not different if a country is in East Asia. If the interaction has a positive beta value, it means that if the country is not in East Asia, then the interaction has a beta and significance value of the smooth PISA score. If the country is in this region, then the sum of the beta of the variables $PISA_{it-6}$ and $PISA_{it-6} * D_{EA}$ will determine the exact effect if they are significant. The overall and interaction betas of PISA math, reading, and science scores were not significant. This means that these test scores do not significantly affect growth in any way.

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Table 2. Regression of the basic models with the full sample between 2006 and 2019

Variables	(1) GDP per capita growth	(2) GDP per capita growth	(3) GDP per capita growth
$PISA_{reading\,it-6}$*	−0.011		
$PISA_{science\,it-6}$*		−0.071	
$PISA_{math\,it-6}$*			−0.003
$pop_{change\,it}$	8.053***	8.558***	8.456***
$openness_{it}$	−0.000	−0.000	−0.000
$life_{exp\,it}$	0.036*	0.057*	0.051*
$invest_{it}$	5.467e-07***	5.421e-07***	5.450e-07***
$govexp_{it}$	−0.011*	−0.011*	−0.011*
Year 2009	0.087**	0.083**	0.085**
Year 2009	0.131***	0.112**	0.117**
Year 2009	0.145**	0.121*	0.127*
Year 2009	0.181**	0.154*	0.1604*
constant	7.733***	6.371***	6.477***
Observations	202	187	187
Number of countries	49	46	46

*PISA scores were divided by 100.
Notes: *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$. The panel models use country fixed effect and year fixed effects; Dependent variable: growth rate in GDP per capita, 2006–2019; sample of all countries which have at least two PISA scores in any year; Independent variable: PISA reading (1), science (2), math (3) 6 years before. Control variables: life expectancy, population change, level of investment, government expenditures and the openness of the economy.
Source: authors.

All in all, the first hypothesis, which states that the increase in PISA scores will have a positive effect on GDP per capita growth in the global sample between 2006 and 2019 is rejected. There were no significant beta values in either model. The second hypothesis, which states that PISA scores in East Asia have had a greater impact on growth than in the rest of the world between 2006 and 2019, should also be rejected in general.

The research has several limitations that need to be mentioned in more detail. In general, the research examines human capital as a dimension through the cognitive skills of 15-year-old secondary school students. The research considers the PISA score effect 6 years later, however, changes during the 6 years and various other factors are not examined in the research.

The second major limitation is the sample length. The shortened sample and the fact that the PISA results are only carried out every 3 years, has resulted in fewer observations. It should be highlighted that only five of the East Asian countries had complete data at least with two points in time. This may be since only some East Asian countries had complete data for all periods, others did not measure certain variables and were therefore excluded from the survey.

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Table 3. Regression of the interaction models with the full sample between 2006 and 2019

Variables	(1) GDP per capita growth	(2) GDP per capita growth	(3) GDP per capita growth
$PISA_{reading\,it-6}$ *	−0.012		
$PISA_{reading\,it-6}$ x Dummy (SEA)*	0.015		
$PISA_{science\,it-6}$ *		−0.057	
$PISA_{science\,it-6}$ x Dummy (SEA) *		−0.300	
$PISA_{math\,it-6}$ *			−0.007
$PISA_{math\,it-6}$ x Dummy (SEA) *			0.179
$pop_{change\,it}$	8.049***	8.5902***	8.463***
$openness_{it}$	−0.000	−0.000	−0.000
$life_{exp\,it}$	0.036*	0.056*	0.051*
$invest_{it}$	5.443e-07***	5.131e-07**	5.220e-07***
$govexp_{it}$	−0.011*	−0.011*	−0.011*
Year 2009	0.087**	0.082**	0.087**
Year 2009	0.131***	0.113**	0.118**
Year 2009	0.145**	0.122*	0.129*
Year 2009	0.181***	0.157*	0.162*
constant	7.738***	6.476***	6.451***
Observations	202	187	187
Number of countries	49	46	46

*PISA scores were divided by 100.
Notes: *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$. The panel models use country fixed effect and year fixed effects; Dependent variable: growth rate in GDP per capita, 2006–2019; sample of all countries whose have at least two PISA scores in any year. Independent variable: PISA reading (1), science (2), math (3) 6 years before and interaction of the PISA scores and East Asian dummy. Control variables: life expectancy, population change, level of investment, government expenditures and the openness of the economy.
Source: authors.

6. CONCLUSION

The general research question was whether higher quality education influences economic growth. A more precise formulation of this is if higher quality human capital measured by learning outcomes at the secondary school level influence economic growth.

The literature review clearly showed that there is limited research that only looks at PISA scores in terms of growth. There are studies on PISA scores for various regions, including East Asia, but not for the whole sample.

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Based on the literature, two hypotheses were tested. The first was that between 2006 and 2019, the global sample of countries' GDP per capita growth will be positively impacted by the rise in PISA scores. The second was that between 2006 and 2019, East Asia's PISA results had a larger impact on growth than in other countries in the sample.

We used growth, measured by the change in GDP per capita as the dependent variable, and PISA scores as independent variables. The research used a sample from 2006 to 2019, which included countries that had administered the PISA test at least twice. A total of 59 countries met this criterion. We used a fixed effect regression model in the research.

The model assumed that PISA test results have an impact on growth 6 years later by using data from Barro and Lee's (2013) database, which evaluated the average years of primary schooling above 15. This data was used to compute the average period of entry into the labor market for PISA test takers. Additionally, we looked at how the PISA results and the East Asian dummy interacted.

Overall, the results suggest that both hypotheses can be rejected, and in general, there is no relationship between PISA scores and growth. Based on the first hypothesis, one of the conclusions of the paper is that the skills of 15-year-olds does not affect growth six years later. Rejection of the second hypothesis implies that PISA scores have no extra role in the growth of East Asian countries. There are several reasons for these results, such as that skills are not necessarily the most decisive part of human capital and the fact that the data covers a relatively short period of time, which makes it impossible to examine long-term trends.

Based on the results, the initial idea, and the overall view in the literature that the PISA results can be used as a good proxy for estimating growth is clearly rejected. On this basis, it is important to underline that a critical attitude is essential when looking at PISA scores, as these scores do not have an independent effect on growth.

A major limitation of the paper is that it treats human capital and skills as one-dimensional. Test scores of 15 year olds is not an inherently weak proxy for skills, but it does not fully capture all aspects of human capital. In addition, the regressions look at a 12-year horizon, and perhaps fails to capture the long-term changes that can fundamentally characterize human capital.

The research could be taken forward in several ways. First, a longer time horizon would be important if the data were available. This would further help to validate the results. It is also important to consider how the PISA measurement, which has delayed due to the Covid-19 pandemic, could be methodologically integrated into the database.

Second, it would be worth looking at other variables not just PISA results, such as a proxy for skills. There are a number of other studies or indicators covering skills that might be of interest in this situation and testing them in the long run in relation to growth might be interesting.

Third, another analysis could delve deeper into the possible mediating role of other country-level variables, such as health indicators, population distribution, infrastructure investments etc., that influence both the PISA results and the economic growth.

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