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Investigating the factors affecting the PISA-based test performance of Asian students*

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Abstract

Purpose — This study investigates the factors affecting the learning outcomes of Asian students.

Methods — The effects of both educational inputs and economic and socioeconomic variables on the PISA scores of 10 Asian countries (Hong Kong, Indonesia, Japan, Singapore, Macau, Korea, Turkey, Israel, Qatar, and Thailand) for the years 2006, 2009, 2012 and 2015 were examined using unbalanced panel data.

Findings — The results show that country-level economic factors strongly affect academic achievement. Furthermore, country-level economic factors dominate the other explanatory factors in the numerical and statistical sense.

Implication — The findings provide valuable information for educators, policymakers, and researchers aiming to develop efficient educational strategies to improve educational quality. Furthermore, the results offer policy suggestions for addressing factors that impact the quality of education both at the national and international levels.

Originality — This research enhances the current body of knowledge by investigating how economic and socioeconomic variables affect students' math, science, and reading performance, particularly emphasizing Asian countries.

Keywords — education, PISA scores, unbalanced panel data, Asian countries

Introduction

The exceptional academic performance of Asian students in PISA has garnered significant attention from policymakers, researchers, and educators. This success can be attributed to a multitude of factors, including the quality of teachers, learning methods, strong work ethics, extensive out-of-school education, genetic and natural abilities, parental involvement, and the home learning environment (OECD, 2013; Tan & Darling-Hammond, 2011; Leung, 2006; Byun & Park, 2012; Bray & Kwok, 2003; Lynn & Meisenberg, 2010; Chao & Tseng, 2002; Schneider & Lee, 1990; Zhao, 2014a, 2014b).

Education quality is paramount for countries, and it is often assessed using international test scores like PISA (Program for International Student Assessment), which serve as indicators of education quality. The factors affecting these outcomes are primarily considered educational inputs. However, earlier studies often overlooked the impact of macro-level country characteristics on student achievement despite significant demographic, social, and economic variations among

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countries. These disparities must be considered when identifying factors affecting student learning outcomes.

This study investigates the factors influencing the educational performance of 10 Asian countries in PISA assessments from 2006 to 2015. It examines the impact of various inputs such as student characteristics, family socioeconomic status, teacher qualifications, and economic factors on PISA scores. Due to variations in countries' participation years, unbalanced panel models account for missing data in different regions and timeframes. The study aims to identify the drivers of student success in PISA evaluations.

This study thus contributes to the literature in three ways:

(i) Understanding international tests such as the PISA is very important to improve education in various aspects. These tests have become increasingly influential on politicians. This study examines the student performance of 10 Asian countries in three fields (reading, science, and mathematics) separately using PISA-based data. The Asia and Pacific region is the most rapidly growing economic bloc globally (Hossain et al., 2022). We selected these nations because they took part in the PISA test, and data availability was a significant factor in our choice.

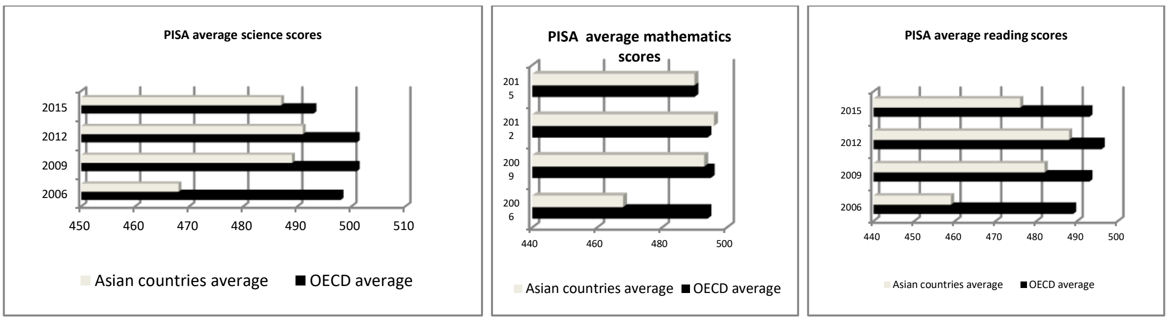
(ii) Prior PISA studies often focused on limited variables, overlooking the multifaceted nature of factors impacting student performance. This study seeks to encompass a broader spectrum of factors affecting students' performance, not only educational but also macroeconomic and socioeconomic aspects. It acknowledges the varying economic contexts among Asian countries.

(iii) Restricted data of the examined Asian countries because of the missing data problem, we use the Unbalanced Panel Data Model that has not previously been used in the studies to our knowledge.

This study is organized as follows: Section 1 presents the introduction. Section 2 introduces the comparison of PISA scores in Asian countries. Section 3 briefly summarizes previous studies on this subject. Section 4 describes the data and variables used. Section 5 discusses the methodology of the study and the findings. Section 6 gives some conclusions and recommendations.

Comparison of Asian countries' PISA scores

PISA is a triennial assessment conducted by the OECD for 15-year-old students in member and partner countries. Several Asian nations began participating in different years, including Hong Kong, Indonesia, Japan, Thailand, Turkey, Israel, Macau, Qatar, and Singapore. Despite Singapore's late entry in 2009, it consistently ranked at the top. In 2006, most Asian countries (excluding Singapore) had science scores below the OECD average. By 2015, Asian countries were nearing the OECD average, with OECD nations scoring an average of 493, while Asian countries averaged around 487 in science scores, as depicted in Figure 1a.

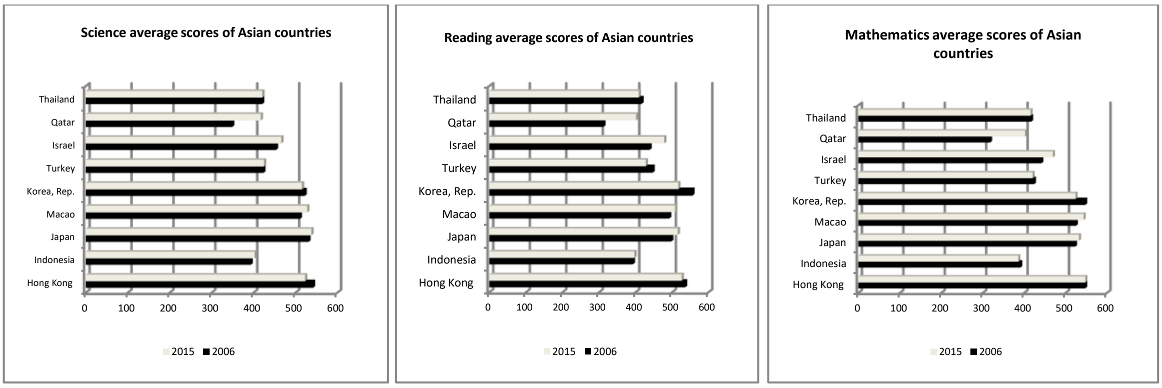


a) b) c)

Figure 1. PISA average scores (science, mathematics, reading)

Figure 1b shows that Asian countries lagged behind the OECD average in mathematics in 2006 but caught up by 2015. However, in reading, Asian countries were significantly below the

OECD average in 2006, and in 2015, they remained below with a score of 476 compared to the OECD's 493 (Figure 1c). So, Asian students reached the OECD math average but fell short in reading and science. Figure 2 displays Asian countries' performance in all three areas in 2006 and 2015. Some exceeded the OECD average, while others did not progress. Overall, China, Macau, Japan, and Hong Kong consistently outperformed, surpassing the OECD average.



a) b) c)

Figure 2. PISA average scores of Asian countries (science, mathematics, reading)

In 2015, students in Japan, Macau, Indonesia, Qatar, and Israel improved their science performance compared to 2006 (Figure 2a). However, Hong Kong and Korea still needed to maintain their 2006 performance. Meanwhile, student achievement in Thailand and Turkey remained relatively stable. In mathematics (Figure 2c), Turkey, Korea, and Indonesia could not match their 2006 performance in 2015. Notably, students in Kuwait, Israel, Macau, Japan, and Indonesia showed improved learning quality in 2015 (Figure 2b).

Many studies have been conducted using different methods for different countries to reveal the factors affecting the success of the countries in the international examination (educational performance) and, thus, the quality of education. The factors affecting student achievement can be categorized into three groups: individual characteristics of the student, family-based, and school-teacher factors (Hanushek & Woessmann, 2011a, 2011b). Among individual characteristics, age, gender, self-confidence, and motivation play pivotal roles. Research by Puhani and Weber (2007) suggests that age can affect academic achievement. Gender differences, as indicated by studies such as those by Pitsia et al. (2017) and Rajchert et al. (2014), also impact performance. Additionally, self-confidence and motivation, as highlighted by Karakolidis et al. (2016), significantly influence academic success. Family-based factors constitute another significant determinant. Parental socioeconomic background, socioeconomic status, parent education, parental earnings, family participation, home learning atmosphere, and family structure contribute significantly. Studies by Coleman et al. (1966), Davis-Kean (2005), Halle et al. (1997), Bouhlila (2017), Marks (2016), Reparaz & Sotés-Elizalde (2019), Schneider & Lee (1990), Pong (1997, 1998), and Manning (1998) shed light on these influences. Finally, school-teacher factors, including school type, size, class size, and instructor skills, also impact academic performance. Research by Aristizábal et al. (2017), Giambona & Porcu (2018), Wilson (2011), Bosworth (2014), and Meroni et al. (2015) highlights the importance of these factors in shaping students' educational outcomes. Understanding these multifaceted influences is crucial for enhancing student achievement and fostering academic success.

As our study primarily concentrated on Asian nations, the literature review revealed that numerous research efforts were undertaken at the national level to investigate the factors influencing student achievement mentioned above.

Research conducted by Pulkkinen and Rautopuro (2022) through correlation analysis has revealed a moderate correspondence between PISA scores and school grades. They found that PISA proficiency scores remain relevant across various subjects, even after considering gender and socioeconomic factors. Lin et al. (2021) employed statistical analysis to demonstrate that gender gaps in reading have narrowed, and there is an overall improvement in educational equity between rural and urban students. This improvement is attributed to changes in the education system, government investment, and cultural factors. Gamazo and Martínez-Abad (2020) utilized data mining techniques to develop a predictive model for school performance. They discovered that educational factors like metacognitive strategies significantly influence student performance in high-SES schools.

In contrast, country-level socioeconomic indicators such as GDP play a more crucial role in low-SES schools. Cheung (2017) employed logistic regression to identify parental and academic background factors to indicate whether a learner in relatively deprived or wealthy contexts is more likely to be categorized as DHA or ALA using PISA 2012 data. Lau and Lam (2017) utilized a linear hierarchical model to show that adaptive training, teacher-driven training, and interactive application benefit educational outcomes across PISA's top-performing regions. Additionally, Meng et al. (2017) used hierarchical multiple regression to highlight the positive effects of training stimuli and student reading approaches on reading outcomes in the United States and China using 2009 PISA data. These studies shed light on various factors influencing academic performance across different contexts and regions. Jerrim (2015) utilized Ordinary Least Squares regression to demonstrate that Australian children with East Asian parents tend to outperform their indigenous Australian peers in mathematics scores.

Similarly, Lam & Lau (2014) employed hierarchical linear modeling, revealing that factors such as being male and born on the mainland positively influence academic success in Hong Kong. Jerrim and Choi (2014) conducted a regression model analysis, concluding that the disparity in math performance between England and East Asian countries remains consistent between ages 10 and 16. Areepattamannil and Caleon (2013) used regression analysis to uncover that memorizing techniques negatively impact math quality in East Asian countries, while control strategies positively correlate with learning outcomes; however, the impact of elaboration strategies varies. Li et al. (2013) employed a Fixed and Random Effects Model to find that U.S. students reading non-continuous texts perform notably better than Shanghai-Chinese students based on 2009 PISA data. Lastly, Sun et al. (2012) utilized multilevel modeling to show that factors such as sex, socioeconomic status, motivation, and self-efficacy are associated with improved science learning outcomes among students in Hong Kong, as per 2006 PISA data. Ho (2010) conducted a multilevel analysis, indicating a significant relationship between parental engagement in cultural capital and early-age science education improvement activities with the science performance of learners, as seen in 2006 PISA data.

This study identifies gaps in prior research on Asian countries' education, such as neglecting combined reading, science, and math performance, single-country or comparative studies, and the absence of panel data analysis. It emphasizes the influence of economic and socioeconomic factors on student achievement. It integrates macroeconomic indicators like GDP per capita, high/low-income nation classification, and human development index to explore their role in student performance disparities.

Methods

The data used are obtained from the World Bank, OECD PISA, UNESCO Institute for Statistics, and United Nations Development Program databases for 2006, 2009, 2012, and 2015. The definitions of the variables are shown in Table 1.

Since Asian countries started to participate in PISA exams in different years, there are deficiencies in the observation values for the variables in different countries and periods. Therefore, estimates are made using unbalanced panel data models in the study. Wansbeek and Kapteyn (1989) and Baltagi and Chang (1994) contributed to unbalanced panel data models. The model used can be described as follows:

$$Y_{it} = \alpha + \beta X'_{it} + u_{it} \qquad i = 1,2,\ldots,N \qquad t = 1,2,\ldots,T \tag{1}$$

where Y_{it} shows the PISA scores that represent student achievement. X_{it} are the independent variables explained in Table 3, and u_{it} is the error term.

Since T=4 years and N=10 countries, (T<N), pooled OLS (POLS) (Baltagi, 2008) was implemented. The POLS is assumed to have no unit and time effects (Gujarati, 2016). POLS estimators can be written as follows:

$$\hat{\delta}_{POLS} = (X'X)^{-1}X'Y. \quad (2)$$

The heterogeneity problem of the model is not regarded, and all cross-sections in the POLS system are viewed as homogeneous (Khan et al., 2019). For the results from the POLS method to be consistent and unbiased, all explanatory variables are expected to be exogenous and uncorrelated to the error term (Quayes, 2015). This study estimates the random effect model using the Generalized Least Squares (GLS) method.

GLS estimators of random-effects models in the unbalanced panel were used in Biørn's (1981) and Baltagi's (1985) studies. The GLS estimators are obtained as follows (Greene, 2012):

$$\hat{\delta}_{GLS} = (X'\Omega^{-1}X)^{-1}X'\Omega^{-1}Y \quad (3)$$

where, Ω, is the variance of v_{it} covariance matrix and can be calculated as follows:

$$\Omega = E(v_i v_i') = \sigma_u^2 I_t + \sigma_u^2 ee'. \quad (4)$$

Since random effect models do not neglect unobserved factors, the parameters of GLS estimators are more efficient than those obtained in the simpler model (Benfratello, 2014). In unbalanced panel models, while GLS is applied, a conversion is performed on the data. Unlike balanced panel models, this conversion process considers the number of observations available for each unit. The OLS method is applied to these converted data.

Table 1. Definition of the variables

Type of variables	Variables	Definition
	Dependent Variable	
Quality of education	PISA scores	Countries' PISA average scores in math, science, and reading.
	Independent Variables	
Family-related factors	Occupational status of parents	Parental occupational status is a variable that takes values from 0 to 100. 100 indicates that the professional status increases.
	Number of certified teachers	The variable that shows the number of certified teachers.
Educational input factors	Use of computers for educational purposes	The average number of computers used for educational purposes.
	Number of students per teacher	Variable showing the number of students per teacher.
	School life expectancy	The overall number of years of schooling that a child should anticipate obtaining.
School related factors		
	School entry age	The level at which pupils are engaged in mandatory education.
	Duration of compulsory education	Period of times during which children are constitutionally required to attend school.
Economic factors	Gross domestic product per capita	GDP per capita based on purchasing power parity.
	High/non-high-income country	A dummy variable with a value of 1 if the economy is a high-income economy and 0 if not.
Socioeconomic factors	Human development index	The human development index takes values from 0 to 1.

Note: All variables are continuous except for the high/non-high income country variable, which is discrete.

Results

Using these methods, factors affecting mathematics, science, and reading scores are estimated separately, and the estimation results are summarized in Table 2.

Table 2. Estimation results

	Generalized Least Squares			Pooled Least Squares		
	Science	Mathematics	Reading	Science	Mathematics	Reading
Constant	7.639*** (0.369)	7.872*** (0.456)	5.303*** (0.929)	7.639*** [0.350]	7.873*** [0.466]	5.303*** [0.680]
Occupational status of parents	-0.016*** (0.002)	-0.018*** (0.003)	-0.013*** (0.003)	-0.016*** [0.002]	-0.018*** [0.003]	-0.014*** [0.003]
Use of computers for educational purposes	0.0009** (0.000)	0.001** (0.0004)	0.002*** (0.0006)	0.0009** [0.0003]	0.001** [0.0004]	0.002*** [0.0004]
School life expectancy (primary)	-0.079*** (0.023)	-0.081*** (0.028)	-0.064* (0.037)	-0.079*** [0.021]	-0.081*** [0.020]	-0.064** [0.030]
Per capita GDP	-0.121*** (0.027)	-0.143*** (0.034)	-0.099*** (0.035)	-0.121*** [0.030]	-0.143*** [0.042]	-0.099*** [0.027]
High/non-high income country	0.367*** (0.050)	0.429*** (0.062)	0.521*** (0.092)	0.367*** [0.051]	0.429*** [0.063]	0.521*** [0.074]
Human development index	0.819*** (0.161)	0.843*** (0.199)	0.430* (0.234)	0.819*** [0.110]	0.843*** [0.163]	0.430** [0.184]
Number of certified teachers	0.002*** (0.0008)	0.003*** (0.001)		0.002** [0.0009]	0.003** [0.001]	
Number of students per teacher	-0.011*** (0.004)	-0.011** (0.005)		-0.011*** [0.002]	-0.011*** [0.003]	
School entry age			0.199** (0.080)			0.199*** [0.049]
Duration of compulsory education			0.077** (0.032)			0.077** [0.031]
	Wald chi2(8) = 278.32*** R^2 =0.930	Wald chi2(8) = 240.82*** R^2 =0.930	Wald chi2(8) =131.09*** R^2 =0.8620	F=52.06*** R^2 =0.930 chi2(1) = 5.93 Prob > chi2 = 0.015	F = 43.12*** R^2 =0.920 chi2(1) = 6.75 Prob > chi2 = 0.009	F=28.79*** R^2 =0.862 chi2(1) = 7.79 Prob > chi2 = 0.005

Breusch– Pagan Lagrange Multiplier Test	Science	Mathematics	Reading
LM Statistics	chi2(1) =1.65 Prob > chi² =0.199	chi2(1) = 0.69 Prob > chi² = 0.407	chi2(1) =1.71 Prob > chi² =0.192
Breusch-Pagan / Cook-Weisberg Heteroskedasticity Test			
BP/CW test statistics	chi2(1) = 5.93 Prob > chi2=0.015	chi2(1) = 6.75 Prob > chi2=0.009	chi2(1) = 7.79 Prob > chi2=0.005

Notes:

i. *, **and *** show statistical significance at the 10%, 5% and 1% levels, respectively.

ii. Robust standard errors are given in square brackets.

iii. The null hypothesis for the Breusch– Pagan Lagrange Multiplier test posits that the variance of the random effect is zero.

iv. The null hypothesis for the Breusch-Pagan/Cook-Weisberg Heteroskedasticity test is that there is no heteroscedasticity.

Table 4 reveals significant coefficients in all models for educational input (e.g., certified teachers, student-teacher ratio, computer use), family-based factors (like parents' occupation), economic indicators (GDP per capita, high/low-income country status), and socioeconomic indicators (human development index) impacting science, math, and reading performance. For reading scores, education system factors (school starting age and compulsory education duration) were statistically significant at 1% and 5% significance levels.

The Wald and F tests rejected the null hypothesis, indicating high overall significance for GLS and POLS models. R-squared values ranged from 86% to 93% for all models. Additionally, the Lagrange Multiplier (L.M.) test, modified for unbalanced panels by Baltagi and Li (1990), helped determine the best method in panel data regression, choosing between common and random effects. For science, mathematics, and reading models, the Breusch-Pagan LM test did not reject the null hypothesis, suggesting unit effects variance is zero, favoring the POLS method over random effects. However, the Breusch-Pagan/Cook-Weisberg Heteroskedasticity test rejected the null hypothesis, indicating heteroscedasticity. Robust standard errors were calculated and presented in Table 4 to address this issue. The study reveals significant findings regarding PISA scores and various influencing factors. Parental occupational status was found to have a negative impact on student performance in science, mathematics, and reading, with a one-point increase in parents' occupational status leading to a 0.02 point reduction in scores. Surprisingly, this suggests that students from low-status families in Asian countries can still attain high academic performance, as seen in China, Singapore, and Japan (OECD, 2014b).

In contrast, an increase in the number of certified teachers positively correlates with higher PISA scores in science and mathematics, in line with prior research by Myrberg (2007) and Kaplan and Owings (2001), emphasizing the importance of teacher professional development for academic success. Additionally, using computers for educational purposes was associated with improved achievement, consistent with the work of Anil and Ozer (2012).

Conversely, an increase in the expectation of primary school education negatively impacts PISA scores by 0.08 units, possibly due to extended class durations and repetition. Likewise, a one-unit increase in the number of students per teacher was linked to a 0.01 unit decrease in scores, indicating that overcrowded classrooms may hinder student performance (Özberk et al., 2017). The effects of economic variables on student achievement vary. The per capita GDP variable has a negative correlation with PISA scores. Research has shown that some economically disadvantaged students can succeed in education despite all the difficulties and problems caused by material deprivation. A different approach means that children from low-income families are working hard to free themselves from such conditions and, therefore, are making more effort to perform academically (Cheang & Goh, 2018). In other words, the low per capita income in Asian countries is a factor that does not impede students' success. PISA scores increase by 0.37, 0.43 and 0.52 units, respectively. One unit increase in the human development index will increase student achievement by 0.82, 0.84, and 0.43 units, respectively. Also, the results indicate that if a country belongs to high-income groups, learning outcomes will be increased by 0.3672, 0.4286, and 0.5210 units, respectively. Two other variables have an impact on reading skills. These factors are the age of admission and the length of mandatory education. One unit rise at the age of beginning school would raise students' performance by 0.2 units, and one unit rise in mandatory education would raise students' success by 0.1 units. The presence of a positive association between school entrance age and learning outcomes is analogous to the studies conducted by Bedard and Dhuey (2006) and Fredriksson and Öckert (2005).

The findings have shown that for all specifications and estimation procedures, country-level economic factors strongly affect academic achievement. Moreover, country-level economic factors dominate the other explanatory factors numerically and statistically. As described in Section 3, many studies in the Asian context neglected country-level economic factors. However, our results show that GDP per capita influences educational success. Its sign is negative, remarkably different from that of the Finnish and Estonian (Mikk, 2015) and Spanish contexts (Rodríguez-Mantilla et al., 2018), which underlines that the level of family income is no obstacle to educational success in these countries (Cheang & Goh, 2018).

Conclusion

This study underscores the significant impact of economic variables on student performance, highlighting the pivotal role of country-level factors in shaping academic achievement. The findings emphasize that macroeconomic factors influence students' academic success considerably. The study implies that with policies aimed at enhancing teaching and schools, students may have opportunities to improve their academic achievements. These results offer valuable insights for educators, policymakers, and researchers seeking to formulate effective educational policies for enhancing the quality of education. Additionally, the findings provide policy recommendations for addressing the conditions that affect education quality within and between countries. It is worth noting that country-level factors, including economic ones, substantially influence students' academic success, alongside the roles of educators and educational systems, making educational improvement a complex and multifaceted endeavor for nations aiming to enhance educational quality and PISA scores.

Disclosure Statement

The authors reported no potential conflicts of interest.

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