DOI: 10.55643/fcaptp.2.61.2025.4688

Sergiy Londar
D.Sc. in Economics, Professor, First Deputy Director for Scientific Work, State Scientific Institution "Institute of Educational Analytics", Kyiv, Ukraine;
e-mail: londar.sergiy@gmail.com
ORCID: 0000-0003-1838-288X
(Corresponding author)

Oleksandr Bosenko
PhD in Economics, Researcher, State Scientific Institution "Institute of Educational Analytics", Kyiv, Ukraine;
ORCID: 0009-0004-3414-8908

Lidia Londar
PhD in Economics, Associate Professor, Leading Researcher of the Distance Education Sector, State Scientific Institution "Institute of Education Content Modernization", Kyiv, Ukraine;
ORCID: 0000-0002-0873-5664

Marcus Pietsch
PhD in Pedagogical Sciences, Professor, Professorship for Educational Science, in particular Educational Management and Quality Development, Institute of Educational Sciences, Leuphana University of Lueneburg, Lüneburg, Germany;
ORCID: 0000-0002-9836-6793

Received: 31/12/2024
Accepted: 06/04/2025
Published: 30/04/2025

EDUCATION FUNDING AS A DETERMINANT OF THE EDUCATIONAL SYSTEM'S EFFECTIVENESS AND SOCIETAL PERFORMANCE

ABSTRACT

The article aims to analyze approaches to evaluating secondary education effectiveness across various countries by examining the relationship between public expenditures and students' corresponding learning outcomes, as well as broader societal efficiency indicators. The research explores the correlation between general secondary education funding and international PISA assessment results, alongside the relationship between societal efficiency indicators – such as the Human Development Index (HDI) and GDP at Purchasing Power Parity (PPP) – with educational expenditures and investments in research and development (R&D).

The findings demonstrate a non-linear relationship between PISA scores in countries that participated in the 2015, 2018, and 2022 assessments and the cumulative nine-year education funding per 15-year-old schoolchild, expressed in USD at PPP. This relationship is best approximated by an inverted parabola with a peak.

Using PISA 2022 as a case study, the educational characteristics of leading countries (Vietnam, Singapore, Macau, Japan) and underperforming countries (Qatar, Panama, Cyprus, the Dominican Republic, and Thailand) were analyzed. These countries' educational outcomes fall outside the standard deviation range.

Approaches to evaluating the overall efficiency of education systems were also tested, utilizing widely recognized indicators such as the HDI, GDP per capita at PPP, and the share of public expenditures allocated to R&D. A model was developed to analyze the interrelation between the HDI, R&D expenditures, and per-student educational spending in connection with student performance for a group of countries with high R&D investments.

The resulting determination coefficient is R^2 = 69,7% and confirms the statistical significance of this relationship. The model demonstrates that increased R&D spending has a lesser impact on the HDI compared to educational expenditures on secondary education, adjusted for PISA scores. This finding suggests that, even for developed countries, prioritizing human capital general development through educational investment remains more critical than allocating additional resources to the R&D sector.

Keywords: secondary education funding, cumulative educational expenditures at purchasing power parity (PPP), PISA assessment, educational system efficiency, research and development (R&D), Human Development Index (HDI), modelling

JEL Classification: C52, H52, I22, I25

INTRODUCTION

Education is a strategic sector of societal activity, as acquiring an education that meets the current demands of society ensures an individual's better self-realization, higher income, and overall societal success. A sufficient number of educated members within society enables it to form a knowledge economy, develop new technologies, and produce goods and services with high added value, thereby ensuring the overall success of society.

The basic level of education is general secondary education, which most societies aim to provide to all citizens. After obtaining this education, individuals can enter the labour

market and begin full-fledged work, or they may continue their studies in higher or vocational educational institutions. Therefore, ensuring the quality and accessibility of education at this level is crucial for all members of society.

Adequate funding for education is considered one of the most important prerequisites for its development and ensuring its quality. Typically, the lion's share of educational funding is spent on adequate salaries for teachers, attracting the best representatives from the professional community. In a society that respects teachers, education becomes a prestigious sector, and the quality of educational services improves. However, funding is not the only influencing factor. As shown by the example of Qatar, which has a significantly higher level of funding than many other countries, such funding does not guarantee high PISA (Programme for International Student Assessment) results [1].

Figure 1 shows the dynamics of government expenditure on education as a percentage of GDP in countries worldwide, based on World Bank estimates. As can be seen, the situation in most countries is far from optimal: about one-third of countries spend less than 4% of GDP and less than 15% of total government expenditure on education [36]. Moreover, in recent years, this share has shown a downward trend: from 4.4% in 2020 to 3.7% in 2022. Within this overall figure, there are significant differences between individual countries. For example, in the European Union in 2020, the average expenditure on education was 4.7% of GDP, with some countries spending less than 4.0%: Ireland (3.1%), Italy (3.9%), Romania (3.6%), and Bulgaria (3.9%). Meanwhile, countries like Estonia (6.0%), Belgium (6.2%), Denmark (6.3%), and Sweden (6.9%) spent 6.0% or more.

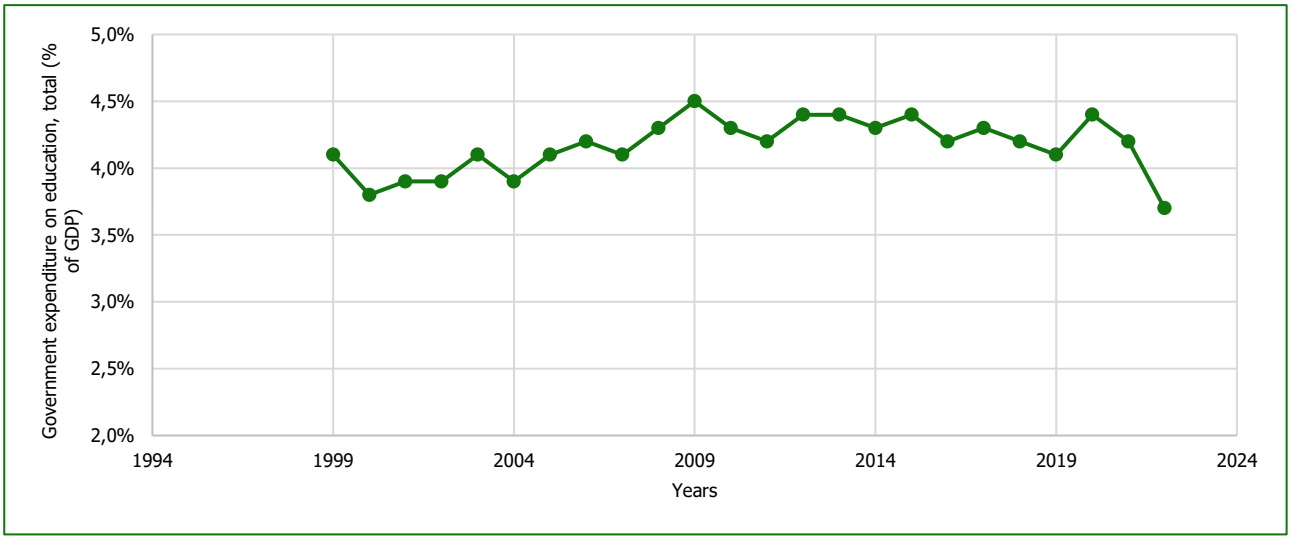

Figure 1. WB: Dynamics of government expenditure on education, total (% of GDP). *(Source: compiled by the authors based on [36])*

The figures mentioned alone may not provide sufficient insight into the quality of education and its impact on broader societal success indicators, such as the level of human development, the development of the national economy, the size of the knowledge economy sector, and so on.

The aim of the article is to examine approaches to evaluating the efficiency of secondary education across various countries of the world to determine the relationship between public spending and corresponding learning outcomes of schoolchildren, alongside broader societal performance indicators.

LITERATURE REVIEW

A number of researchers have studied the factors influencing learning outcomes both at the micro level (schools, courses) and at the macro level (country, regions). Among them are, in particular, Hanushek (1986), Lockheed and Hanushek (1994), Clements (2002), Afonso and Aubyn (2005), Aubyn, Pina, Garcia and Pais (2009), Aristovnik and Obadic (2014), Gavurova, Kocisova, Belas, and Krajcik (2017), Flores (2017), Londar and Buchrushyn (2022, 2023).

However, there is little research to date on the relationship between students' PISA or TIMSS (Trends in International Mathematics and Science Study) scores and economic variables, such as government spending on education, government expenditures on teacher salaries, GDP per capita, etc.

DOI: 10.55643/fcaptp.2.61.2025.4688

Over the last two decades, various scientific approaches have been developed to evaluate the societal effect of financial resource allocation on secondary education. These approaches often rely on PISA results, primarily due to their comparability across many countries worldwide. These approaches continuously evolve, and within them, new methods for analyzing educational data are being developed.

A well-known approach is the use of regression models that correlate educational outcomes with factors such as the socio-economic status (SES) of students. This is an effective approach widely used in PISA assessments. To identify the relationship, various regression models are configured between the resources spent and PISA results. Independent variables used by the authors often include indices representing parental education, income levels, socio-economic status of the households in which students live, and so on. In the study [11], for example, it was shown that funding is a crucial factor influencing academic performance. However, this is insufficient to explain the differences in outcomes for specific student groups in countries like the UK, Spain, and Chile, unless other socio-economic factors are also considered. Authors [4; 12] also confirmed that in many countries, including Ukraine, socio-economic status (SES) is a significant factor that strongly affects student performance. According to the authors, there is a need to strengthen targeted funding to support vulnerable groups of students, particularly those from low socio-economic backgrounds.

The development and adaptation of the Data Envelopment Analysis (DEA) method is another approach that has gained renewed prominence since the mid-2010s and remains effective for evaluating and comparing the efficiency of various educational systems. In particular, this approach has been used [4; 5; 29] to assess the efficiency of the use of various educational resources, including total education expenditure, teacher salaries, and more. To compare the efficiency of different educational systems, the resources spent are compared with students' academic achievements, primarily the easily comparable PISA results, as they are obtained in different countries for students of the same age using the same benchmark. In recent years, the most intensive use of DEA has been associated with studying the efficiency of educational resource spending in OECD countries. The DEA approach has made it possible to identify countries with highly efficient educational systems despite relatively low educational expenditures [5], with the educational systems of New Zealand [3] and Australia [33] being examples of such systems.

In the works [14; 15], the authors demonstrated that the adaptation and use of the DEA method allow for the quantitative assessment of the efficiency of educational resource spending (including budgetary financing) both at the regional level within a specific country and at the level of territorial communities within a region. This type of assessment is of significant practical importance for the use and adjustment of educational policies based on evidence-based data.

Another approach is formed based on a series of Stochastic Frontier Analysis (SFA) methods that developed in the late 2010s. This approach involves modelling educational efficiency by considering the impact of random factors. Unlike DEA, here random deviations are analyzed. In some cases, this allows for a more accurate assessment of the potential impact of external factors, including socio-economic conditions, changes in educational policy, and budgetary funding. For example, in [10], the SFA method was used to analyze the life satisfaction of adolescents in wealthy EU countries and the factors influencing it.

The authors [29] developed a multi-criteria approach based on the ELECTRE method. The models created are suitable for comparing education systems in countries with heterogeneous economic conditions and allow for a comprehensive analysis of the impact of various factors. Using the results of PISA assessments of Serbian students as an example, different profiles of secondary education were evaluated, and an analysis of various education systems was conducted, considering multiple criteria such as the relevance of educational expenditures, quality of education, and social equity.

Figure 2 illustrates the dynamics of the number of publications with the key phrase "evaluation of the efficiency of secondary education financing." As can be seen, in the early 2010s, the average number of publications recorded annually in the WebScience database was around 10. In contrast, in the last 4 years (2021-2024), this number has increased to an average of 35. Thus, the research interest in this topic has steadily grown.

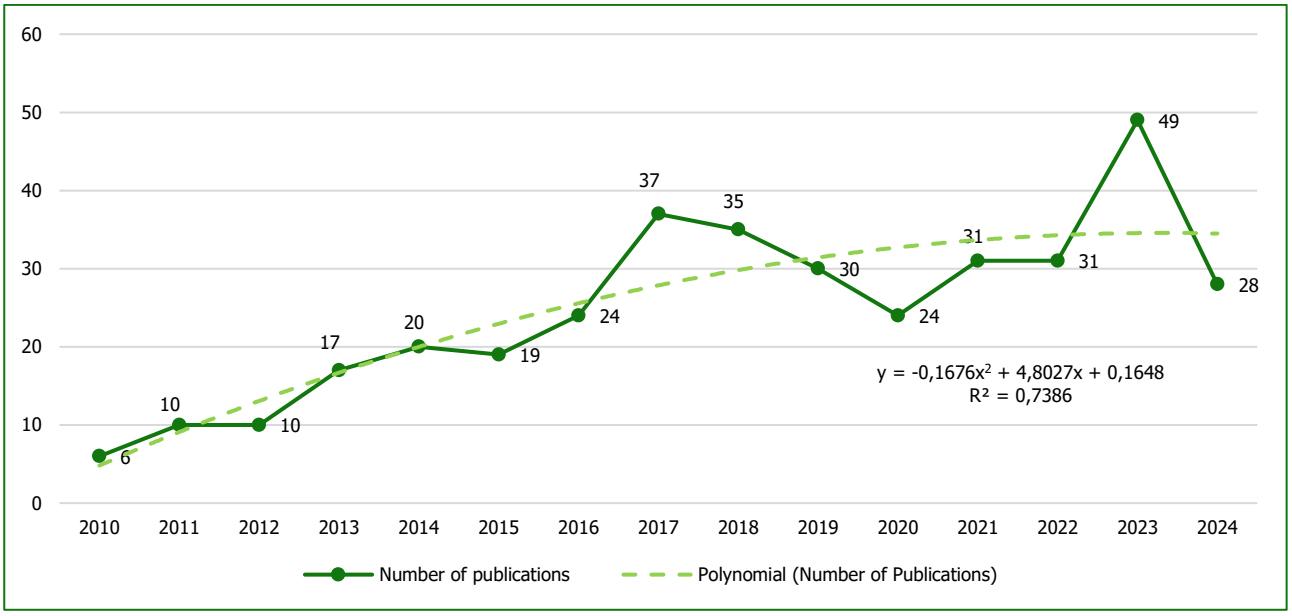

Figure 2. Dynamics of the publications numbers in the WebScience database during 2010-2024 by keywords "evaluation of the effectiveness of secondary education funding." *(Source: compiled by the authors using data from the WebScience database [34])*

Figure 3 presents the countries of publications origin authors registered in the WebScience database under the keywords "evaluation of the effectiveness of secondary education funding." The pictogram is created using the VOSviewer application.

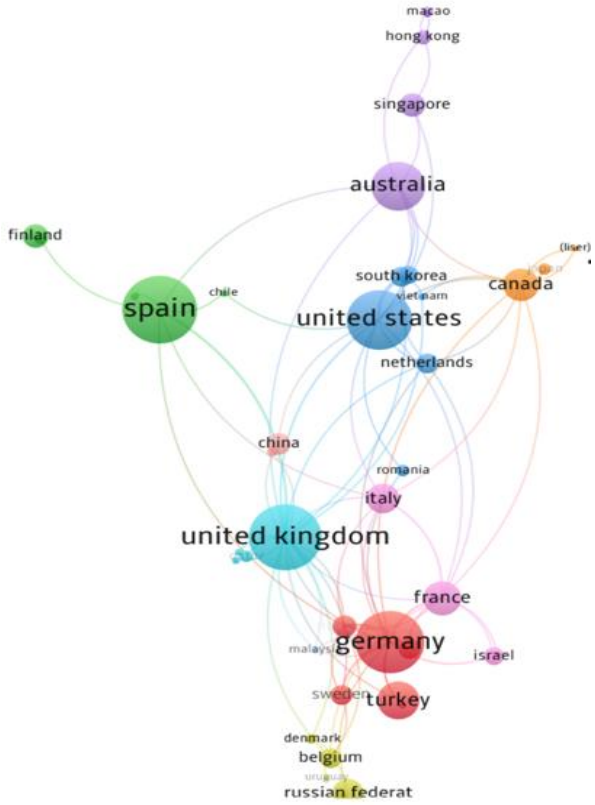

Figure 3. Countries associated with the authors of publications in the WebScience database by the keywords "evaluation of the effectiveness of secondary education funding." *(Source: built by the authors based on data from the international scientometric database Scopus using the VOSviewer application [30])*

DOI: 10.55643/fcaptp.2.61.2025.4688

It is evident that research in this area is most intensively conducted by researchers from Spain, the USA, the UK, and Germany, while such studies are relatively scarce in post-Soviet countries.

Therefore, studies focused on identifying the relationship between the level of funding and the results of international student assessments through standardized tests, as well as the link between these public expenditures and corresponding indicators of overall societal success, are highly relevant.

AIMS AND OBJECTIVES

The aim of the article is to explore approaches to assessing the effectiveness of secondary education in various countries financed by public funds, identifying the relationship between these public expenditures and the corresponding student performance results as well as overall societal success indicators. The key objectives of the study are to assess the correlation between cumulative educational expenditures on 15-year-old students and their PISA results, conduct a model analysis of the relationship between overall societal success (indicator: Human Development Index) and the presence of a knowledge economy segment (indicator: R&D), and the financial efficiency of secondary education (per capita expenditure per student relative to academic performance).

METHODS

The study employs a comprehensive approach that includes an analysis of the scientific literature, documents from international organizations, and statistical data. The analysis of international organizations' documents was conducted to understand various approaches to regulating education funding. A comparative analysis was used to examine the best and worst practices of countries regarding the effectiveness of educational funding, allowing the identification of successful strategies and initiatives, as well as potential reasons for poor PISA results in some countries despite relatively good financial support. This approach helps identify best practices that can be adapted for implementation in Ukraine.

Statistical analysis of PISA performance indicators and cumulative funding was employed to determine the countries with the most effective education systems. This method allows for generalizing the positive features of these countries' education systems and formulating recommendations for implementing the best approaches in Ukraine's education system.

Correlation analysis was used to determine the time lag effect of R&D funding spent by knowledge-based economies on the Human Development Index (HDI). This method enables an evaluation of the duration of science-intensive investments and their impact on overall societal success.

Regression modelling was used to analyze the dependence of overall societal success on the development of the knowledge economy segment and the financial efficiency of secondary education in various countries.

The study used comparable indicators for evaluating secondary education across all countries. In many research works, PISA assessment results are selected as such indicators. Since PISA data is obtained in different countries for students of the same age under the same normative framework, the results of the study can be easily compared, providing a unique opportunity for international comparative research.

RESULTS

Figures 4, 5, and 6 illustrate the relationship between the average PISA score in OECD countries and partner countries in the subjects of mathematics, reading, and science. Additionally, the figures show the relationship between each of these subjects and the cumulative 9-year education expenditures for 15/16-year-old students participating in the PISA assessments in 2015, 2018, and 2022.

For all three data sets, efforts were made to find a common approximation curve with the best correlation indicators. Logarithmic and polynomial dependencies were tested. Based on the testing results, the inverse quadratic dependence showed the closest correlation, suggesting the possibility of a certain maximum. This form of the curve demonstrates that increasing the cumulative 9-year financial expenditures on education for 15/16-year-old students in the pool of PISA-participating countries leads to a nonlinear increase in the student's academic performance, which reaches a certain maximum. Further increases in financial expenditures on education lead to a decrease in students' learning outcomes.

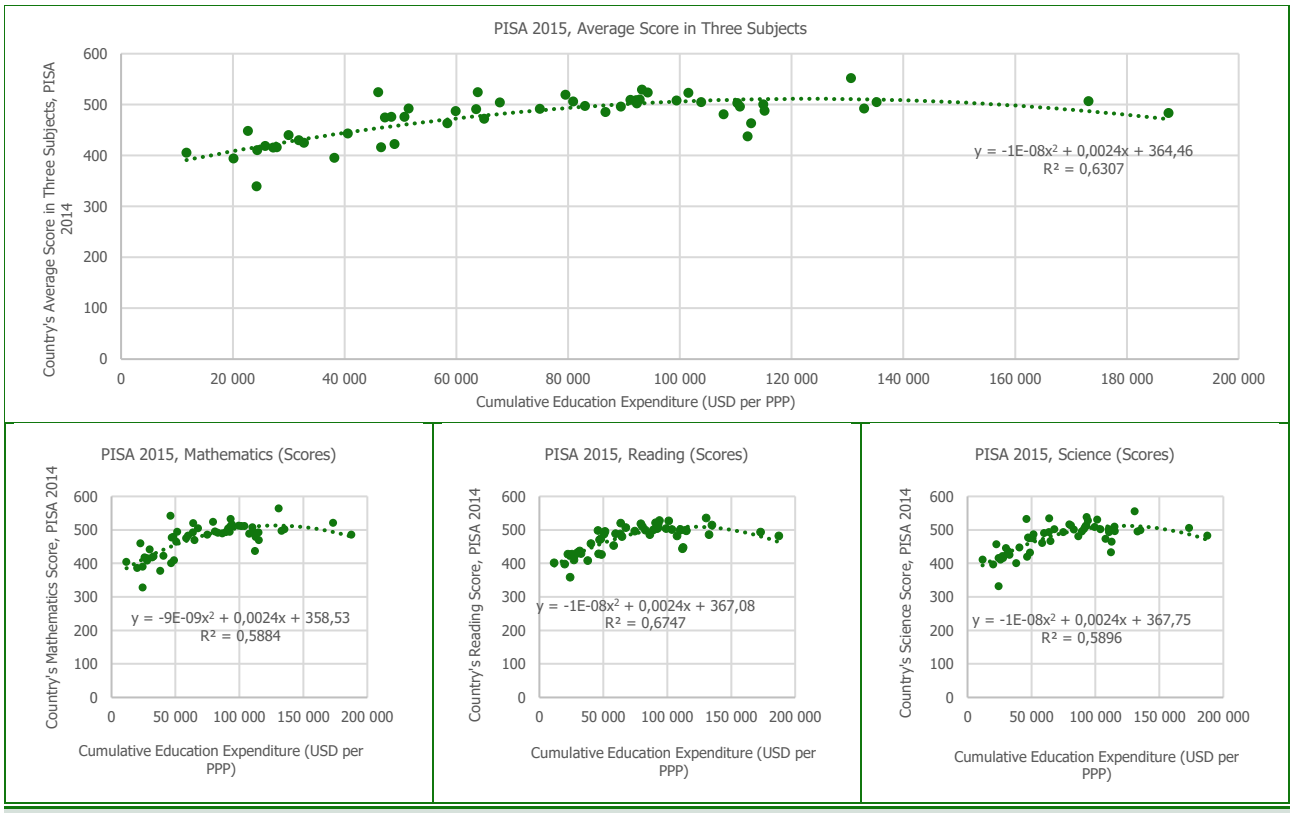

Figure 4. Dependence of the average PISA 2015 score (mathematics, reading, science) for OECD countries and partner countries on the cumulative 9-year financial expenditure on education of 15/16-year-old students who participated in PISA assessments. *(Source: compiled by the authors based on [22])*

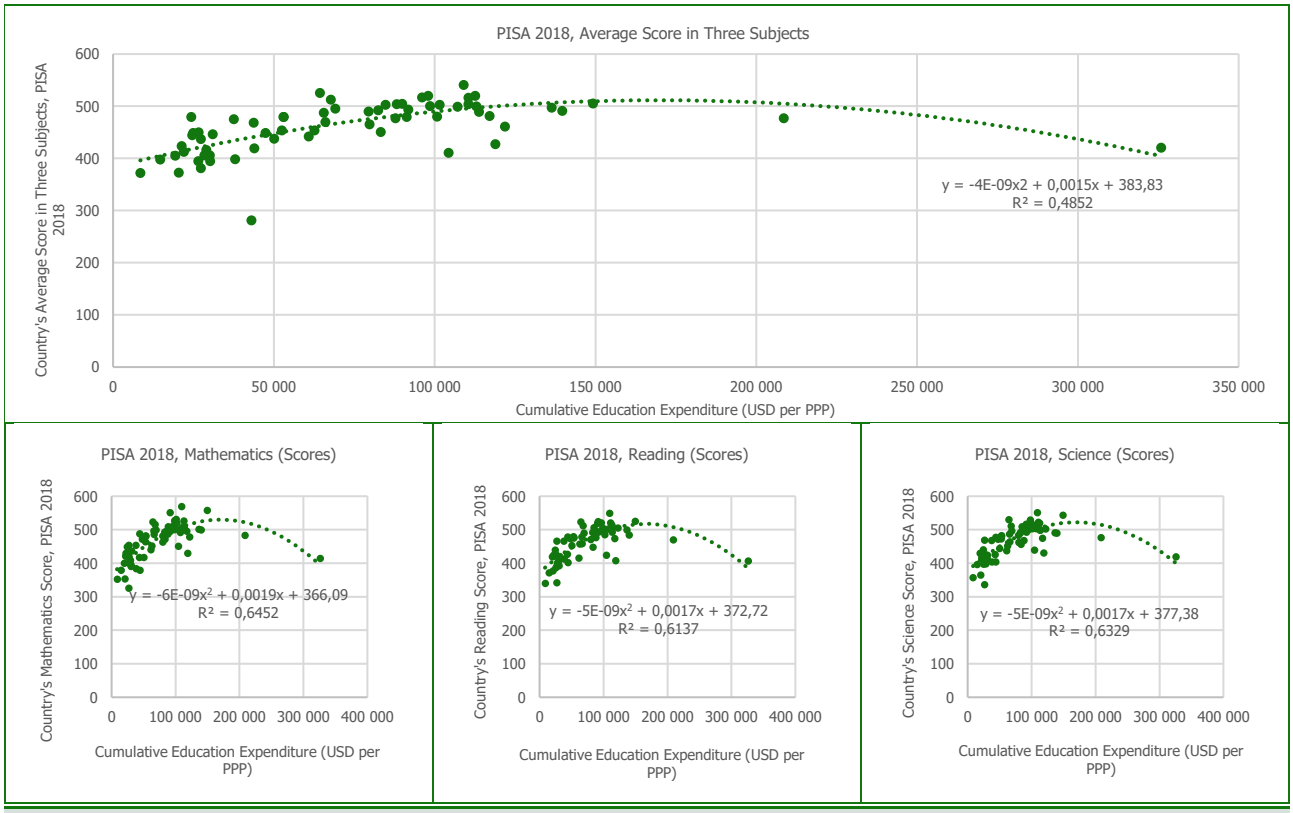

Figure 5. Dependence of the average PISA 2018 score (mathematics, reading, science) for OECD countries and partner countries on the cumulative 9-year financial expenditure on education of 15/16-year-old students who participated in PISA assessments. *(Source: compiled by the authors based on [23])*

DOI: 10.55643/fcaptp.2.61.2025.4688

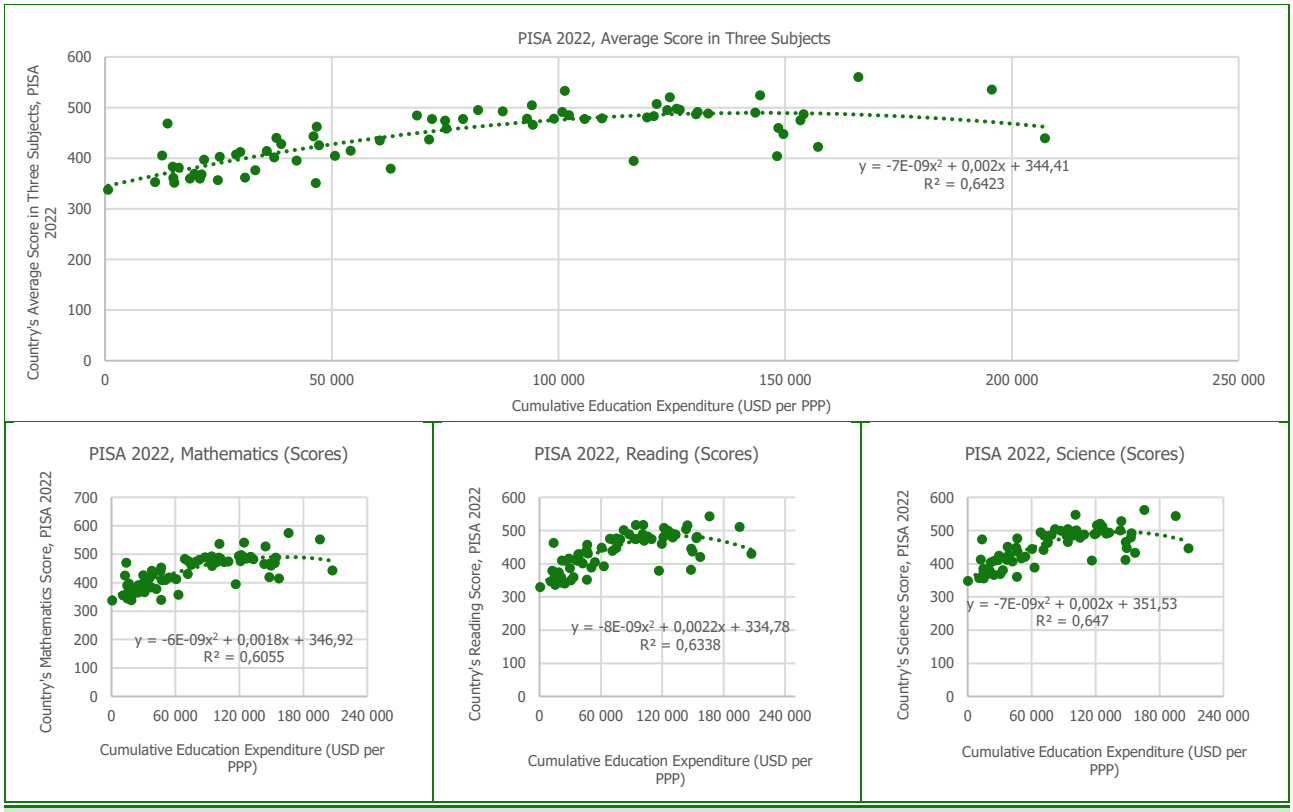

Figure 6. Dependence of the average PISA 2022 score (mathematics, reading, science) for OECD countries and partner countries on the cumulative 9-year financial expenditure on education of 15/16-year-old students who participated in PISA assessments. *(Source: compiled by the authors based on [24])*

Figure 7 presents a comparison of the volume of other educational expenditures with the share of educational expenditures allocated to personnel (aggregated for 2014, 2018, and 2022) across OECD countries. As shown, there is a significant correlation (the coefficient of determination is $R^2 = 0.54$), indicating a regularity: in less affluent countries, where other educational expenditures are low, almost all educational expenditures are directed towards supporting personnel. In wealthier countries, such relative expenditures are significantly smaller.

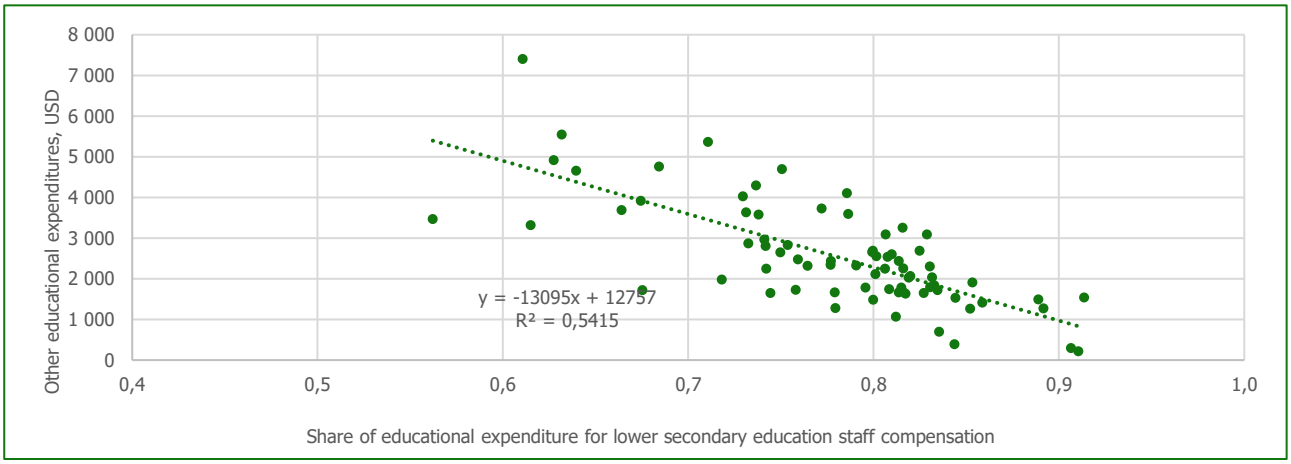

Figure 7. Dependence of the educational expenditures share on staff performance on the volume of other educational expenditures (on the example of lower secondary education in OECD countries in 2014, 2018, 2022). *(Source: compiled by the authors based on [18;19;20])*

This dependence can partially explain the presence of an optimum in educational expenditures for ensuring PISA results (Figures 4-6): in countries with high levels of educational funding, a significant portion of educational expenditures is directed towards developing educational infrastructure, which does not provide an immediate return in terms of student outcomes. In contrast, expenditures on personnel yield such returns, and the share of personnel expenditures is higher in poorer countries.

Using the results of PISA-2022, we constructed the standard deviations of educational outcomes for this dataset (Figure 8) and identified the leading and lagging countries, where the educational outcomes lie outside the standard deviation limits (Table 1).

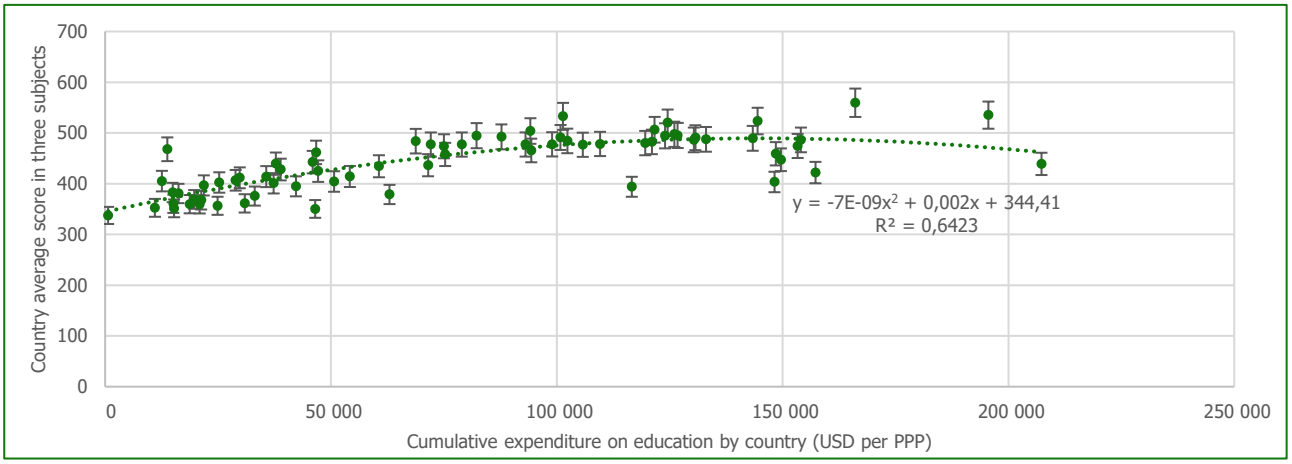

Figure 8. Standard deviations of countries' learning outcomes for the PISA-2022 data set. *(Source: compiled by the authors based on [24])*

Table 1. Leading and lagging countries with PISA 2022 results outside the standard deviation. *(Source: built by the authors based on [24])*

Countries	Cumulative cost per student (USD per full-time equivalent student)	Average score in three PISA subjects	Average score in three PISA subjects according to the quadratic model	The difference *Y-model*	Deviation of the average score from the limited standard error
Leading countries	***X***	***Y***	***Model***		
Viet Nam	13 773.1	467.9	370.6	97.3	+47.3
Singapore	166 111.9	559.6	483.5	76.1	+26.1
Macao (China)	195 581.0	535.1	467.8	67.3	+17.3
Japan	101 399.3	532.7	475.2	57.5	+7.5
Lagging countries					
Panama	62 970.9	378.8	442.6	-63.8	-13.8
Qatar	157 277.7	421.9	485.8	-63.9	-13.9
Dominican Republic	46 517.0	350.3	422.3	-72.0	-22.0
Cyprus	148 201.6	403.4	487.1	-83.6	-33.6
Thailand	116 619.5	394.0	482.4	-88.5	-38.5

Thus, based on the previous analysis, it has been identified that the educational systems of countries such as Qatar, Panama, Cyprus, the Dominican Republic, and Thailand demonstrated poorer results, while the best-performing educational systems were found in Vietnam, Singapore, Macao (China), and Japan.

This result is supported by other studies that specifically examined the educational systems of these countries. For example, the relatively low PISA results in Qatar are explained by researchers [1] as being, among other factors, due to the unsuccessful educational reform "Education for the New Era" (ENE). Under this reform, all state schools in Qatar were transformed into charter (independent) schools with broad decision-making powers regarding pedagogical, managerial, and financial matters. However, by 2016, the management of education returned to greater centralization due to irreconcilable contradictions with achieving the main goals of the reform. There was no balance found between global and national visions of the essence of education and its role in the development of society. The process and outcomes of the reform caused dissatisfaction among government authorities and the population. Thus, despite high levels of funding, PISA results were relatively low.

On the other hand, the low PISA results of Panamanian students in 2022 are interpreted by researchers [2] as clear evidence of the inefficiency of the overly centralized state education system. Such centralization in Panama hinders innovations necessary to improve the quality of education, and the low success in mathematics and natural sciences indicates insufficient attention to the development of practical and analytical skills.

DOI: 10.55643/fcaptp.2.61.2025.4688

Cyprus students also demonstrated a decline in mathematics, natural sciences, and reading in PISA-2022. The Ministry of Education [7] of Cyprus identified the key problem in the education system as its focus on knowledge dissemination rather than developing students' skills and abilities. A number of reform initiatives were outlined, including revising curricula, introducing new teaching methods, modernizing educational assessment systems for students and teachers, implementing early intervention programs, digitizing education, and integrating innovative programs with a focus on critical thinking development.

The education system of the Dominican Republic also shows low PISA results and significant unresolved issues, including poor teaching quality, unequal access to education, and inadequate funding. Investments in education since 2013 have been at 4% of GDP, but structural problems remain, particularly in rural and impoverished areas. Researchers [6] attribute the insufficient educational outcomes in PISA assessments to:

- low teaching quality (only 33% of teachers passed the professional competence test, indicating deficiencies in both knowledge and pedagogical methods);
- resource inequality (significant differences in resources between urban and rural schools, with many schools overcrowded and lacking basic amenities such as drinking water, electricity, and modern communication technologies);
- systemic corruption (insufficient control over the allocation and use of resources, particularly financial);
- the impact of COVID-19 (many students in remote areas lacked access to online education due to the absence of internet and devices, exacerbating educational inequality).

Thailand consistently ranks low in education quality assessments compared to other countries, especially in mathematics and science. According to PISA 2022 results, Thailand failed to significantly improve its position from previous years, ranking 57th in mathematics and 53rd in science out of 78 countries.

The Thai government and educational experts acknowledge the need for reforms in the education system [32]. Recently, the "Big Five" model has gained popularity, focusing on developing qualities in students such as resilience, growth mindset, and self-discipline. This approach aims to address the negative trends observed in PISA assessments and reflects an awareness of the need for comprehensive educational reforms.

In contrast to these countries, the educational systems of countries like Vietnam, Singapore, Macao (China), and Japan are recognized for their success.

Vietnam [8;26;27] shows extraordinarily high PISA results, attributed to several reforms and factors influencing its education system. The primary reason for its success is the significant changes made to the education system after the 1986 economic reforms, which led to the establishment of private schools, thereby expanding access to education and improving the quality of teaching. Currently, Vietnam continues reforms aimed at addressing educational inequality between different socio-economic groups, where students from wealthier families significantly outperform those from less privileged backgrounds.

New teaching approaches have been introduced with an increased emphasis on practical knowledge. According to PISA data, Vietnamese students spend more than 17 hours per week on extracurricular activities, one of the highest rates among all participating countries. Vietnamese students demonstrate very high discipline in class. Other factors contributing to success include: 1) a focus on core subjects, particularly mathematics, science, and reading; 2) professional development programs for teachers and significant investments in modernizing school infrastructure and adopting new technologies; 3) a system for selecting and supporting teachers, including competitive hiring processes and continuous professional development; and 4) fostering a culture of educational support from parents and the community, which helps cultivate strong student discipline.

Singapore [9;25;31;35] is a global leader in education, with consistently high PISA results in reading, mathematics, and science. In 2022, Singaporean students achieved the highest scores in all three subjects out of 81 countries, with the highest proportion of students reaching advanced levels.

Key factors contributing to Singapore's success include significant investments in education, and a high level of teacher support at all levels, with 86% of students reporting that teachers provide additional help during mathematics lessons. Innovative teaching methods that offer personalized approaches for each student play a crucial role. A strong focus is placed on developing critical thinking, mathematical and scientific reasoning, and helping students quickly adapt to changes in the digital world.

Key PISA success factors in Singapore are: 1) the development of innovative teaching technologies with an emphasis on critical thinking and creativity; 2) teacher training and continuous learning systems, teacher support to ensure high qualification levels, and the use of the latest teaching methods tailored to individual student needs; 3) targeted support for students with a personalized approach to education, ensuring equal access to education for all social groups; 4) educational reforms that focus on preparing students for future professions requiring high technical and scientific knowledge, aligned with global labour market demands.

Singapore continues to be a model for other countries in educational reforms, and its education system remains one of the best in the world.

The education system of Macao [16;21] is also one of the most effective in the world. According to the PISA 2022 results, students in Macao ranked second in mathematics and third in science, demonstrating a high level of academic success. They also ranked in the top 10 for reading, securing seventh place among the 81 participating countries. This confirms the effectiveness of their education system across three key subjects: mathematics, reading, and science. The OECD further notes that Macao's education system is distinguished by its high level of inclusivity. The country was able to improve its results even during the COVID-19 pandemic, further demonstrating the effectiveness of its educational reforms.

Overall, Macao's education system has been recognized for its ability to maintain academic success at the international level while providing a multicultural learning environment. It ensures the inclusion and support of various social groups.

Japan [13;37] shows significant success in its education system according to PISA results. In 2022, Japanese students ranked third in the world for reading literacy, significantly improving from 15th place in 2018. Japan also ranked second in science and fifth in mathematics. These achievements are the result of educational reforms, particularly the introduction of new curricula that focus on developing critical thinking and the ability to express one's thoughts. An important factor was Japan's ability to maintain school operations during the COVID-19 pandemic with minimal interruptions, preventing significant disruptions in the learning process, unlike many other countries.

Japan continues to lead in mathematics and science, where it ranks among the highest in PISA assessments, alongside other Asian countries. Success factors include a strong focus on teaching quality, maintaining educational equity, and ensuring high levels of inclusivity and access to education for all students. According to the OECD, Japan's education system is considered one of the best in terms of equity in education.

To evaluate the overall effectiveness of the education system, it is crucial to understand its impact on the country's success in various aspects. Since general secondary education is a fundamental level of education, its impact on society can be significant. For assessing national and societal success, commonly used indicators such as the Human Development Index (HDI), which accounts for various aspects of citizens' well-being, GDP per capita (PPP), which reflects economic dynamics, and the share of public expenditures on R&D (which indicates the level of development in knowledge, technology, and science sectors) can be considered.

In this context, we tested the correlation between the average scores of the three subjects assessed by PISA and GDP per capita (PPP) for two groups of countries: those with low R&D expenditures (up to 0.9% of GDP) and those with high R&D expenditures (0.9–5.6% of GDP). The results are shown in Figure 9.

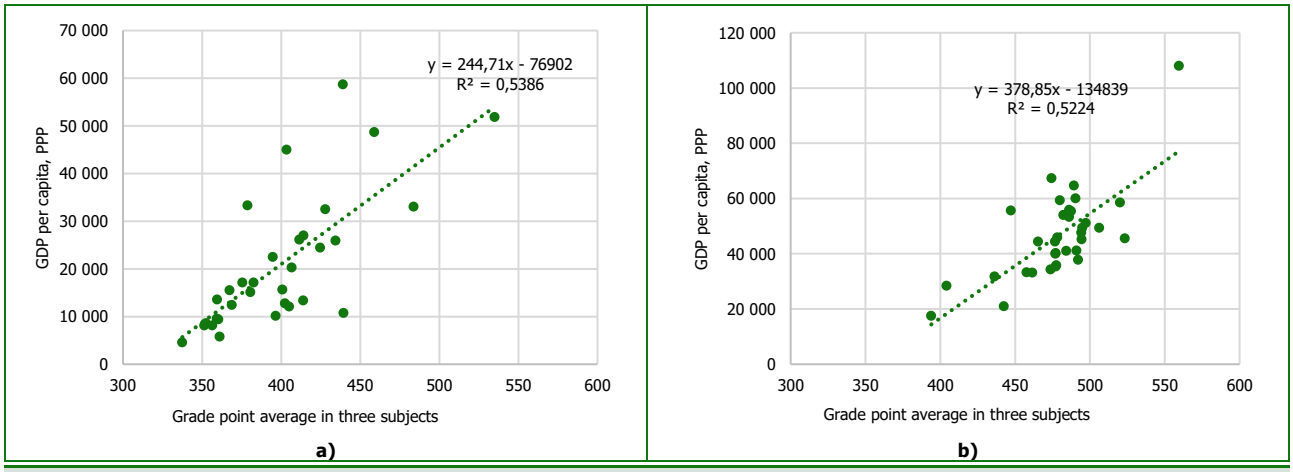

Figure 9. Dependence between the average score in the three subjects assessed by PISA and GDP per capita (PPP) for two groups of countries. Note: a) Countries with low R&D expenditures (up to 0.9% of GDP); b) Countries with high R&D expenditures (0.9–5.6% of GDP. *(Source: built by the authors based on [28])*

DOI: 10.55643/fcaptp.2.61.2025.4688

As seen in the figures, the Gross Domestic Product (per capita, in terms of purchasing power parity) is related to the average score in the three subjects assessed by PISA. In countries with low R&D expenditures (up to 0.9% of GDP), an increase of one unit in the average score translates, on average, into USD 244.7 (PPP). In contrast, in countries with higher R&D expenditures (ranging from 0.9% to 5.6% of GDP), this value is, on average, 1.5 times higher, reaching USD 378.9 (PPP). The question of whether the "average score" or "GDP" is the causal factor requires further investigation. This could be achieved, for example, by studying the impact of time lags on this relationship. In any case, this relationship is significant and can be interpreted as the importance of education for a country's economic development and the creation of a knowledge-based economy.

Figure 10 shows the change in the correlation coefficient as the lag between the data series representing R&D expenditures and the Human Development Index (HDI) values changes for developed countries in the "maximum" range of the curve in Figure 8 (the second group of countries with high R&D funding).

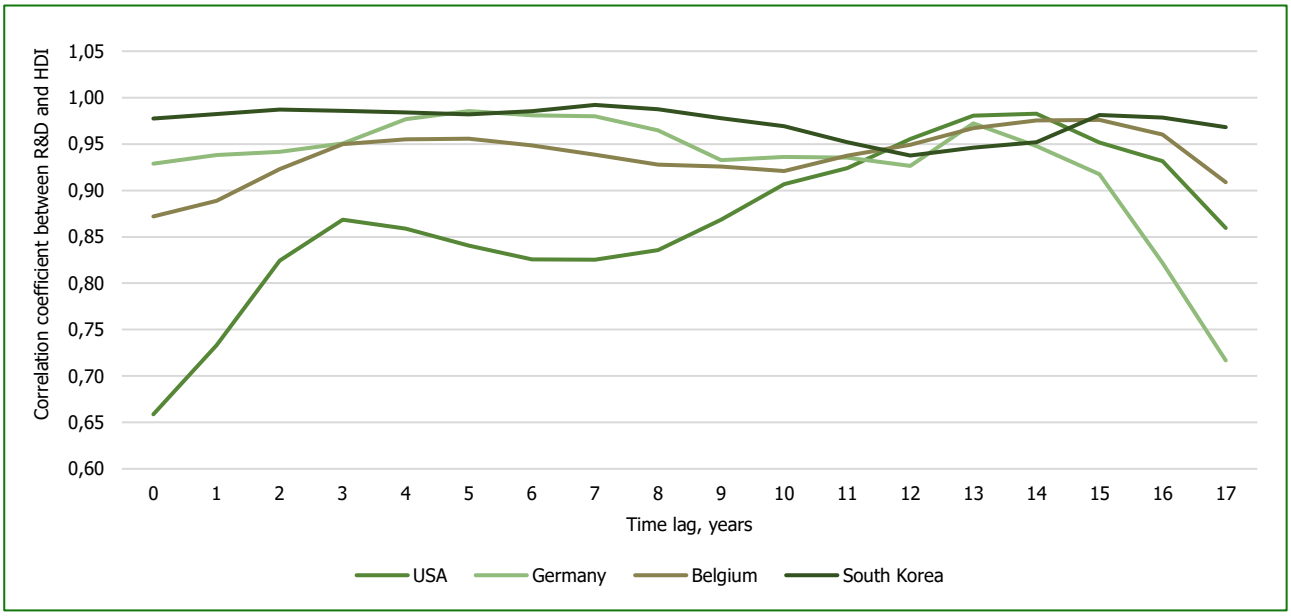

Figure 10. Change in the correlation coefficient with varying lag between the data series representing R&D expenditure (% GDP) and the Human Development Index (HDI) for some developed countries (USA, Germany, Belgium, South Korea). *(Source: built by the authors based on [28])*

As shown in the figure, the general pattern is that the correlation coefficient has two maxima, one related to the near-term perspective (3-6 years), and the other to the more distant perspective (10-15 years). This result can be interpreted as indicating that investments by developed countries in the knowledge economy segment (through R&D) improve the state of society within a few years, while also laying the foundation for further improvements in the longer term.

To assess the relative impact of the education system on the success of society, we conducted a modelling of the relationship between the HDI (Y) and the possible influencing factors: R&D expenditure (% GDP) ($\boldsymbol{X_1}$) and the relative value of "Calculated cumulative expenditure on educational institutions per student (USD, PPP)" / Average score across the three PISA-assessed subjects" ($\boldsymbol{X_2}$) for the 2021-2022 data.

The values of $\boldsymbol{X_1}$ and $\boldsymbol{X_2}$ were normalized by using the formula:

$$\boldsymbol{X}_{\textbf{1,2 normalized}} = (Xi-Xmin)/(Xmax-Xmin) \quad (1)$$

The modelling resulted in a linear relationship:

$$\boldsymbol{Y_{teor}} = 0.839+0.\boldsymbol{008X_1} + \boldsymbol{0.133X_2} + \varepsilon \quad (2)$$

A description of the model statistics is presented in Table 2.

Table 2. Statistics of the model represented by formula (2). *(Source: built by the authors based on [28])*

	value				***value***		
1	0.133	0.008	0.839	**1**	a_2	a_1	a_0
2	0.019	0.021	0.009	**2**	sea_2	sea_1	sea_0
3	0.697	0.024		**3**	R^2	*seY*	
4	35.760	31		**4**	*F*	*df*	
5	0.042	0.018		**5**	*ssreg*	*ssresid*	

Table 2 uses the following notations: a_0, a_1, a_2 – values of the constant coefficients in the linear equation; sea_0, sea_1, sea_2 – values of the standard errors for these constant coefficients; R^2 – the coefficient of determination; *seY* – the standard error of the resulting variable; *F* – the Fisher statistic value; *df* – degrees of freedom; *ssreg, ssresid* – values of the sum of squares for regression and residual sum of squares, respectively.

The coefficient of determination is R^2 = 69.7%, indicating a significant relationship between the Human Development Index (HDI) – Y, R&D expenditures (% of GDP) X_1, and per capita educational spending related to student success X_2 in the group of countries with high R&D expenditures.

The model was tested for significance using Fisher's method, and the relationship is significant. No heteroscedasticity or autocorrelation was detected.

In the group of countries with low R&D expenditures, no such relationship was observed (the coefficient of determination was not significant).

The model's results for the group of countries with high R&D expenditures can be interpreted as follows: A one-point increase in the normalized value of R&D expenditure leads to a 0.008% increase in the Human Development Index, while a rise in the normalized value of average educational spending, adjusted for PISA scores, leads to a 0.133% increase in the Human Development Index. This means that educational expenditures are currently more important than R&D expenditures and may be related to the greater significance of improving overall human potential (capital), especially considering that a large part of the economy in even developed countries has yet to fully transition into a knowledge economy.

DISCUSSION

Developed countries demonstrate that more than half of their GDP is generated by human capital and the intellectual contribution of citizens residing in these countries. General secondary education provides the longest period of formal education and lays the foundation for basic knowledge and skills, making it a key component of human capital. This motivates almost all countries to provide government financial support to the education sector. By allocating budget resources to general secondary education, each society aims to use them effectively which involves achieving the highest possible educational outcomes with available expenditures. However, the concept of educational system efficiency is multidimensional. By comparing allocated funds with specific educational outcomes, we assess the efficiency of a country's educational system in the short term. It is also important to develop an approach for a comprehensive evaluation of educational system efficiency, taking into account both the long-term period and the balance between short-term and long-term societal impacts.

This study explored the possibilities of evaluating the efficiency of government spending on secondary education in different countries in the short term by identifying the relationship between such societal expenditures and the corresponding educational outcomes of students, as assessed in the international PISA evaluation. Additionally, the study examined various aspects of the long-term impact of financing general secondary education, specifically exploring the relationships between such funding and a range of societal success indicators, such as the Human Development Index (HDI), GDP at PPP, R&D expenditure, and others.

The obtained results revealed the nonlinear nature of the increase in PISA scores: as per capita educational funding increases, educational outcomes first reach a maximum and then decrease (Figures 4, 5, 6). Nonlinear results for PISA 2015 concerning educational funding and GDP were also observed by other authors [17]. They noted that up to a certain threshold, increasing the flow of money into education leads to improved educational outcomes. Beyond this point, this effect disappears. One explanation relates to the fact that in countries with the highest levels of educational funding, a larger portion of the educational expenditure is directed toward the development of educational infrastructure, equipment,

DOI: 10.55643/fcaptp.2.61.2025.4688

etc. This does not have an immediate impact on student outcomes (Figure 7). In poorer countries, nearly all spending is directed toward personnel, resulting in quicker returns. However, other influencing factors likely exist and should be explored in future research.

The article also proposes a method for identifying the most and least efficient educational systems in the short term by analyzing the standard deviations of PISA scores from the approximating curve. By analyzing PISA 2022 data, leading countries (Vietnam, Singapore, Macao, Japan) and lagging countries (Qatar, Panama, Cyprus, Dominican Republic, Thailand) were identified, where educational outcomes lie beyond the standard deviation range. This result is confirmed by several other studies that specifically examined the characteristics of the educational systems in the mentioned countries.

To identify long-term effects, we examined the relationships between secondary education funding and societal success indicators, such as the Human Development Index (HDI), GDP at PPP, R&D expenditure, and others.

All countries that participated in the PISA evaluations were divided into two groups: one with low (up to 0.9% of GDP) and one with high (0.9% - 5.6% of GDP) levels of R&D expenditure. The second group includes high-tech countries that require well-educated personnel for this.

To assess the contribution of new technologies to the successful functioning of society, we analyzed the change in the correlation coefficient between R&D expenditure and the Human Development Index. For the first group of countries, the correlation is almost absent. For the second group, this correlation exists in most countries. The general pattern is that for countries with high correlation, the coefficient of correlation with a time shift shows two maxima, one related to the near term (3-6 years) and the other to the more distant future (10-15 years). This may indicate that investments made by developed countries in the knowledge economy segment improve society's well-being within a few years and lay the foundation for further improvement in the longer term.

To compare the impact of secondary education funding and R&D funding on societal success, we performed regression modelling using data from the group of countries with high R&D expenditure. The obtained coefficient of determination R2 = 69.7% confirms the significance of this relationship. The model shows that an increase in R&D expenditure has a smaller impact on the Human Development Index than educational spending on secondary education, adjusted for PISA scores. This means that, for these countries, educational spending is currently more important than R&D spending. This may be related to the fact that, even for developed countries, ensuring a sufficient labour force for the economy remains more important, given that much of the economy has yet to transition into a high-tech knowledge economy. Authors [17], who used the National Democracy Index, noted that such countries typically exhibit high PISA results, a high democracy index, and high GDP per capita.

Overall, this research should be continued, particularly by conducting a comprehensive study of educational efficiency with multiple inputs/outputs using the adapted DEA method [14; 15]. Another avenue for future research could be developing an approach to evaluate the efficiency of educational funding in countries experiencing extraordinary circumstances.

CONCLUSIONS

The issue of evaluating the effectiveness of budgetary support for general secondary education is of global relevance, as general secondary education is a key element in the educational trajectories of citizens in all countries and plays a fundamental role in the development of human capital.

The study formulates a framework for assessing the effectiveness of general secondary education that is funded from the state budget. A comprehensive assessment should take into account both the short-term and long-term impacts of such financing. In the short term, the effect can be evaluated based on comparable student achievements, such as PISA results, while in the long term, general indicators of societal success should be used. However, since these general indicators are influenced by many factors, further research is needed to identify the specific impact of the educational component.

ADDITIONAL INFORMATION

AUTHOR CONTRIBUTIONS

Conceptualization: *Sergiy Londar, Marcus Pietsch*

Data curation: *Oleksandr Bosenko, Lidia Londar*

Formal Analysis: *Sergiy Londar, Oleksandr Bosenko, Lidia Londar*

Methodology: *Lidia Londar, Oleksandr Bosenko*
Software: *Oleksandr Bosenko*
Resources: *Oleksandr Bosenko*
Supervision: *Sergiy Londar*
Validation: *Sergiy Londar, Lidia Londar*
Investigation: *Lidia Londar, Oleksandr Bosenko*
Visualization: *Sergiy Londar, Oleksandr Bosenko*
Project administration: *Sergiy Londar, Lidia Londar*
Funding acquisition: *Oleksandr Bosenko*
Writing – review & editing: *Sergiy Londar, Lidia Londar*
Writing – original draft: *Sergiy Londar, Lidia Londar, Marcus Pietsch*

ACKNOWLEDGMENT

The authors are grateful to Volodymyr Buchrushyn (Doctor of Physical and Mathematical Sciences, Professor) for the substantive discussions of the article and to Ivan Haiduk (PhD in Economics) for assistance with information support.

FUNDING

The Authors received no funding for this research.

CONFLICT OF INTEREST

The Authors declare that there is no conflict of interest.

REFERENCES

1. Abdel-Moneim, M. A. (2020). Between Global and National Prescriptions for Education Administration: The Rocky Road of Neoliberal Education Reform in Qatar. International Journal of Educational Development, 74, 102160. https://doi.org/10.1016/j.ijedudev.2020.102160
2. Acosta Roberts, O. (2022). Análisis Crítico al Estilo Sobre los Resultados de Panamá en PISA 2022. https://es.linkedin.com/pulse/an%C3%A1lisis-cr%C3%ADtico-al-estilo-sobre-los-resultados-de-en-acosta-roberts-cqoze.
3. Alexander, W. R. J., Haug, A. A., & Jaforullah, M. (2010). A Two-Stage Double-Bootstrap Data Envelopment Analysis of Efficiency Differences of New Zealand Secondary Schools. *Journal of Productivity Analysis, 34*(2), 99–110. http://www.jstor.org/stable/41770919
4. Avvisati, F. (2020). The Measure of Socio-Economic Status in PISA: A Review and Some Suggested Improvements. *Large-scale Assessments in Education, 8*(1), 8. https://doi.org/10.1186/s40536-020-00086-x
5. Crato, N. (2021). Setting up the Scene: Lessons Learned from PISA 2018 Statistics and Other International Student Assessments. In Improving a Country's Education, edited by N. Crato, 1–16. Springer, https://doi.org/10.1007/978-3-030-59031-4_1
6. CRS Reports. "Data Pandas." (n.d.). https://www.oecd.org/en/publications/pisa-2022-results-volume-i-and-ii-country-notes_ed6fbcc5-en/dominican-republic_18177a60-en.html
7. Cypriot Students Show Declining Trends in Mathematics, Sciences, and Comprehension (A Review of 2022 PISA and ICCS Results). (2022). https://fastforward.com.cy/educational/cypriot-students-show-declining-trends-mathematics-sciences-and-comprehension
8. Dang, H. A. H., Glewwe, P., Lee, Y. J., & Vu, T. D. (2020). School Governance, Education Quality, and Inequality: Evidence from Vietnam. RISE Programme. https://riseprogramme.org/sites/default/files/2020-11/RISE_WP-036_Dang_Glewwe_Lee_Vu.pdf
9. Kwek, D. et al. (2023). Educational Reforms and Innovations in Singapore. Brookings. https://www.brookings.edu/articles/singapores-educational-reforms-toward-holistic-outcomes/
10. Ferrera, J. M. C. (2015). Success Factors for Educational Attainment in Europe: An SFA Approach. *Revista de Educación, 370*(4), 172-198. https://doi.org/10.4438/1988-592X-RE-2015-372-288
11. Gurak, R. (2023, December 05). Results of PISA 2022 Emphasize Competency-Based Learning. State Service for Quality of Education of Ukraine. https://sqe.gov.ua/rezultaty-pisa-2022/
12. Holovko, M., & Naumenko, S. (2024). Results of PISA 2022 in Ukraine: Current Issues in General Secondary Education and Ways to Address Them. Ukrainian Pedagogical Journal, 2, 35–50. https://doi.org/10.32405/2411-1317-2024-2-35-50

DOI: 10.55643/fcaptp.2.61.2025.4688

13. Japan Site Homepage. (2023). OECD Japan. https://www.oecd-ilibrary.org/sites/53f23881-en/index.html?itemId=/content/publication/53f23881-en&_csp_=de697f9ada06fe758fbc0d6d8d2c70fa&itemIGO=oecd&itemContentType=book

14. Londar, S., Bakhrushyn, V., Gapon, V., Londar, L., Pron, N., & Dmytriieva, M. (2024). Assessment of the Efficiency of Budgetary Funding of General Secondary Education in Ukraine. *Financial and Credit Activity: Problems of Theory and Practice, 1*(54), 564–577. https://doi.org/10.55643/fcaptp.1.54.2024.4290

15. Londar, S., Bakhrushyn, V., Londar, L., Gapon, V., & Pron, N. (2022). Ways to Improve the Budget Support of School Education Development in Ukraine. *Educational Analytics of Ukraine, 5*(21), 5–24. https://doi.org/10.32987/2617-8532-2022-5-5-24

16. Macao's Education Performance in OECD PISA Results Shows Improvement in Mathematics. (2023, December 06). Macao News. https://macaonews.org/news/city/macau-education-oecd-pisa-results-maths-macao/

17. Mazurek, J., & Mielcová, E. (2019). On the Relationship Between Selected Socio-Economic Indicators and Student Performances in the PISA 2015 Study. Technical University of Liberec. http://hdl.handle.net/11025/34877

18. OECD. (2015, November 24). Education at a Glance 2015. OECD Publishing. https://doi.org/10.1787/eag-2015-en

19. OECD. (2019, September 10). Education at a Glance 2019: OECD Indicators. OECD Publishing. https://doi.org/10.1787/f8d7880d-en

20. OECD/UIS/Eurostat. (2024, September 10). Education at a Glance 2024: OECD Indicators. OECD Publishing. https://doi.org/10.1787/e7d20315-en

21. OECD. (n.d.). Macao - Education GPS: OECD's Education and Skills. https://gpseducation.oecd.org/CountryProfile?plotter=h5&primaryCountry=MAC&treshold=10&topic=PI

22. OECD. (n.d.). PISA 2015 Results (Volume I): Excellence and Equity in Education. OECD Publishing. https://doi.org/10.1787/9789264266490-en

23. OECD. (n.d.). PISA 2018 Results (Volume I): What Students Know and Can Do. OECD Publishing. https://doi.org/10.1787/5f07c754-en

24. OECD. (n.d.). PISA 2022 Initial Reports (Volumes I and II). OECD Publishing, 2022. https://doi.org/10.1787/5f07c754-en

25. OECD. (n.d.). The Singapore Education System: A Global Benchmark (PISA 2018 Country-Specific Overview). https://www.oecd.org/content/dam/oecd/en/about/programmes/edu/pisa/publications/national-reports/pisa-2018/featured-country-specific-overviews/PISA2018_CN_SGP.pdf

26. OECD. (n.d.). Vietnam - Education GPS: OECD's Education and Skills. https://gpseducation.oecd.org/CountryProfile?primaryCountry=VNM&treshold=10&topic=PI

27. Open Development Vietnam. (n.d.). PISA 2022: Vietnamese Students Experience a Decline in Performance Rankings. https://vietnam.opendevelopmentmekong.net/news/pisa-2022-vietnamese-students-experience-a-decline-in-performance-rankings/

28. Research Spending as a Percentage of GDP. (n.d.). Our World in Data. https://ourworldindata.org/grapher/research-spending-gdp

29. Stamenković, M., Anić, I., Petrović, M., & Stojanović, J. (2016). An ELECTRE Approach for Evaluating Secondary Education Profiles: Evidence from PISA Survey in Serbia. *Annals of Operations Research, 245*(1), 337–358. https://doi.org/10.1007/s10479-015-1823-7

30. Scopus. (n.d.). Explore Scopus. Scopus. https://www.scopus.com/home.uri?zone=header&origin=sbrowse

31. Singapore Ministry of Education. (n.d.). Ministry of Education Singapore. https://www.moe.gov.sg/

32. The Nation Thailand. (n.d.). Thailand: PISA 2022 Results Show Decline in Student Performance. The Nation. https://www.nationthailand.com/thailand/general/40034012

33. Wanke, P., Blackburn, V., & Pestana Barros, C. (2016). Cost and Learning Efficiency Drivers in Australian Schools: A Two-Stage Network DEA Approach. *Applied Economics, 48*(38), 3577–3604. https://doi.org/10.1080/00036846.2016.1154560

34. Web of Science. (n.d.). Explore Web of Science. https://webscience.org/

35. World Bank. (2024). Education Overview: Singapore Overview. https://www.worldbank.org/en/country/singapore/overview

36. World Bank. (n.d.). Government Expenditure on Education, Total (% of GDP). https://genderdata.worldbank.org/en/indicator/se-xpd-totl-gd-zs?view=trend&geos=WLD

37. Shimbun, Y. (2023, December 06). Japan: School Safety a Growing Concern as Number of Bullying Incidents Rises. The Japan News. https://japannews.yomiuri.co.jp/society/general-news/20231206-154074/

Лондар С., Босенко О., Лондар Л., Пітч М.

ФІНАНСУВАННЯ ОСВІТИ ЯК ЧИННИК ФОРМУВАННЯ ЕФЕКТИВНОСТІ ОСВІТНІХ СИСТЕМ І ПОКАЗНИКІВ УСПІШНОСТІ СУСПІЛЬСТВА

Метою дослідження є аналіз підходів до оцінювання ефективності середньої освіти в різних країнах світу через визначення взаємозв'язку між державними витратами й відповідними результатами навчання школярів і ширшими суспільними показниками ефективності. Досліджено зв'язок обсягу фінансування загальної середньої освіти з результатами міжнародних оцінювань PISA, а також зв'язок між показниками суспільної ефективності, зокрема індексом людського розвитку (ІЛР), ВВП за паритетом купівельної спроможності (ПКС) із освітнім фінансуванням, витратами на наукові дослідження й розробки.

Показано, що результати PISA країн, які брали участь у міжнародних дослідженнях PISA 2015, 2018 та 2022 років, мають нелінійну залежність від обсягу кумулятивного дев'ятирічного фінансування, вираженого в доларах США за паритетом купівельної спроможності, витраченого на освіту одного 15-річного школяра. Ця залежність найкраще апроксимується перевернутою параболою з максимумом.

На прикладі PISA-2022 було проаналізовано освітні характеристики країн-лідерів (В'єтнам, Сінгапур, Макао, Японія) та країн-аутсайдерів (Катар, Панама, Кіпр, Домініканська Республіка, Таїланд), освітні результати яких виходять за межі діапазону стандартного відхилення.

Апробовано також підходи до оцінки загальної ефективності освітньої системи з використанням таких загальновизнаних показників, як індекс людського розвитку (ІЛР), ВВП на душу населення за паритетом купівельної спроможності, частка державних видатків, яку спрямовують на розвиток сектора досліджень і розробок. Розроблено модель для аналізу взаємозв'язку між індексом людського розвитку (ІЛР), витратами на НДДКР і витратами на освіту в розрахунку на одного студента у зв'язку з успішністю студентів для групи країн із високими витратами на НДДКР. Отриманий коефіцієнт детермінації R^2 = 69,7% підтверджує значущість цього зв'язку. Модель показує, що збільшення видатків на дослідження й розробки (R&D) менше впливає на індекс людського розвитку порівняно з освітніми видатками на середню освіту, скоригованими на бали PISA. Це може свідчити, що навіть для розвинених країн фінансування загального розвитку людського капіталу залишається більш пріоритетним, порівняно з фінансуванням сектора досліджень і розробок.

Ключові слова: фінансування середньої освіти, сукупні витрати на освіту за паритетом купівельної спроможності (ПКС), оцінка PISA, ефективність освітньої системи, дослідження та розробки (R&D), індекс людського розвитку (ІЛР), моделювання

JEL Класифікація: C52, H52, I22, I25

DOI: 10.55643/fcaptp.2.61.2025.4688