MPRA
Munich Personal RePEc Archive

Empirical Assessment and Comparison of Educational Efficiency between Major Countries across the World

Chen, Lipeng and Yu, Yang and Addis, Amsalu K. and Guo, Xiao

Research Center of Open Economy, Hubei University, Wuhan 430062, China, School of Business, Hubei University, Youyi Avenue, Wuchang District No. 368, Wuhan 430062, China, School of Education, Hubei University, Wuhan 430062, China

February 2022

Online at https://mpra.ub.uni-muenchen.de/112562/
MPRA Paper No. 112562, posted 04 Apr 2022 08:54 UTC

Research Center of Open Economy *WP/22/001*

Published in: Sustanability

Empirical Assessment and Comparison of Educational Efficiency between Major Countries across the World

Lipeng Chen [1,2,#], Yang Yu [3,*,#], Amsalu K. Addis [1,2] and Xiao Guo [3]

[1] Research Center of Open Economy, Hubei University, Wuhan 430062, China; lpchen07@163.com (L.C.); amy.kid370@gmail.com (A.K.A.)

[2] School of Business, Hubei University, Youyi Avenue, Wuchang District No. 368, Wuhan 430062, China;

[3] School of Education, Hubei University, Wuhan 430062, China; 18506152013@163.com

* Correspondence: yuyang20140037@126.com; Tel.: +86-13018093236

[#] These authors contributed equally to this work

Abstract: Education is a fundamental factor to enhance a country's comprehensive national strength and international competitiveness. Recently, several governments have been attracting investments in educational sectors in contemplation of meliorating a country's overall strength. This study empirically assesses and compares the educational efficiency of 29 major countries across the world using panel data for 2010–2016 by employing data envelopment analysis (DEA) and the super-slacks-based measure (super-SBM) model at the static level combined with the Malmquist index (MI) to investigate educational efficiency at the dynamic level. The results indicate, inter alia, huge average education efficiency differences existed among the studied countries, the highest being Japan (3.2845) and lowest Norway (0.4137), there are differences in the bias of technological progress among the studied countries during the sample period and technological progress directly affects the sustainability of educational efficiency, the growth rate of total factor productivity (TFP) index has been reduced in 2010–2013 but increased in 2014–2016 and technological progress has been the dominant factor influencing the rise of the education TFP index. Based on the results, this study identifies the merits and drawbacks of education efficiency across the sample countries and presents relevant recommendations to promote investment in the education sector and human capital.

Keywords: Educational efficiency; Super-SBM model; Malmquist index; Total factor productivity (TFP) index; Data envelopment analysis (DEA)

1. Introduction

Since the turn of the 21st century, international competition has become increasingly fierce, and the key to their competition is the burgeoning of science and technology, which is also a comprehensive national strength. The competition of science and technology across the world depends on the number of talented human capital, and the training of talents is based on an efficient education system. Arguably, for all intents and purposes education is one of the primary factors of development. No country across the globe can achieve sustainable economic development and improve national strength without substantial investment in human capital [1–4]. Hence, education is commonly assumed to be the fundamental factor to enhance a country's comprehensive national strength and nourish international competitiveness, but to date, the evidence for this assumption has been surprisingly weak. In addition, in recent years, many governments have been increasing funding and incentivizing domestic and foreign investments in educational sectors in a bid to improve a country's comprehensive strength by improving the level of education. However, does high investment input convey high output?

With the increasing investment in educational sectors, many countries are facing the mismatch between education demand and education resource supply to varying degrees [5,6]. Should countries necessitate investing more in education to promote economic growth and sustainable development? How to boost the quality of educational investment and the level of educational efficiency in order to realize the significance of education for sustainable development has become a hot issue [1,7–9]. Undoubtedly, clarifying these problems has very important theoretical and practical significance for the future direction of educational development in various countries. Therefore, this paper attempts to present the nonparametric data envelopment analysis (DEA) method from the perspective of international comparison and examine educational development sustainability by employing the data obtained from the World Bank education statistics-all indicators database, the United Nations Educational, Scientific and Cultural Organization (UNESCO) education database, and the OECD education and patents statistical database. This paper analyzes and compares 29 major countries with different development levels, and studies their current situation of educational efficiency.

"Educational efficiency" is a compound concept, which first appeared in the book titled, Equality of Educational Opportunity by Coleman [10]. Since it was put forward, countless scholars have conducted in-depth and extensive discussion and research on the connotation and extension of the concept [4,11]. The international comparison of educational efficiency has always been a less concerning issue in educational academia; thus little work has been done on this matter. Most scholars' research on educational efficiency mainly includes two aspects, such as research methods and research objects. (i) From the perspective of research methods, several scholars mainly focused on quantitative analysis and mostly combined it with the use of the production function model. Nowadays, the most widely used analysis methods include stochastic frontier analysis (SFA) of parametric methods, Solow residual analysis (SRA), and data envelopment analysis (DEA) of nonparametric methods. For instance, Titus and Eagan [12] measured the production efficiency of American higher education by using the SFA method and put forward countermeasures and suggestions for the application of the SFA model in higher education. Additionally, Rządziński and Sworowska [13] evaluated the efficiency of 27 higher vocational colleges in Poland based on SFA and DEA methods. They believe that the size and scale of teaching may influence the efficiency of school educational activities, and recommended that the DEA-VRS model should be applied for the efficiency evaluation of higher education institutions. Similarly, Izadi, Johnes, Oskrochi, and Crouchley [14] used stochastic frontier analysis to estimate the cost efficiency of British universities and Johnes [15] illustrates the application of the DEA method in the field of higher education technical and scale efficiency in England. Besides, Sibiano and Agasisti [16,17] used the DEA analysis method to examine educational efficiency brought by educational input and output in different regions of Italian junior middle school and put forward solutions accordingly. (ii) From the perspective of research objects, scholars have also studied educational efficiency, for instance, Dincă, Dincă, Andronic, and Pasztori [18] employed the mathematical approach of DEA to compare the educational efficiency of 28 EU countries and concluded that the educational efficiency of the old member states was generally higher than that of the new member states. Likewise, Xu and Liu [4] also used the DEA method to explore and compare the relationship between education efficiency and national development in major international countries from two aspects of education, input and output. Additionally, Johes and Yu [19] evaluated the input–output efficiency of scientific research of higher education institutions in China and concluded that comprehensive universities consistently outperform specialist institutions and the level of efficiency depends on subjective measures of research output. Moreover, Guccio, Martorana, and Monaco [20] evaluated the impact of Italian university reform on educational efficiency by employing bootstrapped DEA algorithms and indicated that universities have become more efficient progressively. Başkaya and Klumpp [21] also compared the different educational efficiency of public universities and private universities in Germany by calculating the efficiency of input and output of education. In a like manner, Yalçin and Tavsancil [22] studied the efficiency of educational input–output of some schools in Turkey and conclude that quality differences among schools are prominent due to limited off-campus study. Al-Bagoury [23] analyzed the efficiency of educational input–output of higher education institutions in 15 African countries and their environmental influences. However, these studies have been limited on the input–output efficiency of education and lack extensive education quality assessments that are comparable.

Furthermore, we can understand that, *first*, the existing literature mostly used quantitative analysis for the research of educational efficiency, mainly based on the traditional DEA static model, and lacks in-depth investigation of the efficiency of the dynamic DEA model. *Second*, most of the previous literature that studied educational efficiency focused on the research of higher education institutions' efficiency, and the perspective of analysis on the overall educational efficiency is fewer. *Third*, the existing literature focused on the domestic or regional level and there is little literature on the international comparison and assessment of educational efficiency. *Fourth*, while examining the educational efficiency index, only a few studies took the sustainable development of education into consideration. Therefore, this paper attempts to assess, analyze, and compare the overall education efficiency and sustainability of major countries across the world through the super-slacks-based measure (super-SBM) model combined with the Malmquist total factor productivity (TFP) index, based on the national-level panel data of 29 countries from 2010 to 2016, aiming to clarify the overall educational efficiency level, compare and analyze the education development status of various countries, suggest a reasonable allocation of educational resources, and contribute to the academic research.

2. Materials and Methods

The contribution of this study mainly focuses on measuring, analyzing, and comparing the efficiency of education and technology among international countries in the given sample period using the DEA model. The evaluation of education and technology efficiency can foreground the effective utilization of budget and resources. In addition to human capital growth, efficient education in a given country has a prominent effect on economic development [18,24]. Therefore, it is reasonable to evaluate the efficiency of education and technology.

Due to the integrity and availability of data, the sample period of this paper is selected from 2010 to 2016. After excluding countries with less education input and output data, this study selected 29 sample countries across the world and classified them into two, developing economy and developed economy, based on the UN economic classification (See Table 1). The selection criteria of these sample countries are, inter alia, these countries are recognized as the world's largest economies, high education expenditure, and little work has been done on the comparative perspective. The total education expenditure, per capita education expenditure, and the proportion of education expenditure in GDP of these countries are distributed at all levels, with obvious differences. Furthermore, from the perspective of geographical location, these 29 countries are distributed in all regions of the world's five continents and have good geographical representation. From the perspective of the education economy, the economic volume of the sample countries accounted for 79.72% of the world's total economic volume in 2021 (calculated according to the World Bank's GDP data in 2020). Therefore, it is conducive to providing a good sample in data quality.

There are some limitations of the study. In the traditional measurement of productivity, there are often capital input and labor input. Due to the inability to obtain the human capital input of various countries in education such as the efficiency of teaching staff and graduation rate of students, and some countries' index statistics quality is not thoroughly consistent; thus, this paper primarily uses the data of capital input in the input–output index system of educational efficiency, which could be the main defect of this paper and could be an indication for future research.

Table 1. Sample countries and classifications.

Continents	Countries	Developed	Developing	OECD	Non-OECD
Africa	South Africa		√		√
America	Argentina		√		√
	Brazil		√		√
	Canada	√		√	
	Chile		√	√	
	Costa Rica		√	√	
	Mexico		√	√	
	United States	√		√	
Asia	China		√		√
	Japan	√		√	
	Israel	√		√	
Australia	Australia	√		√	
Eurasia	Russia		√		√
Europe	Austria	√		√	
	Czech Republic	√		√	
	Finland	√		√	
	France	√		√	
	Germany	√		√	
	Hungary	√		√	
	Ireland	√		√	
	Italy	√		√	
	Norway	√		√	
	Poland	√		√	
	Portugal	√		√	
	Slovak Repub-	√		√	

	lic		
	Spain	√	√
	Sweden	√	√
	Switzerland	√	√
	United King-dom	√	√

2.1. Super-SBM Model

The DEA method is a nonparametric method used to evaluate the relative effectiveness of the same type of multi-input and multi-output decision-making units (DMU) [25,26]. The basic models include Charnes–Cooper–Rhodes (CCR), which works under the assumption of constant returns to scale, and Banker–Charnes–Cooper (BCC), which works under the assumption of variable returns to scale [27]. These models improve the invalid DMU by adjusting the proportion of all inputs or outputs, which is called the radial DEA model. However, for ineffective DEA, the gap between the current state and the strong effective target value, except for the part with equal proportion improvement, does not consider the "Slacks" impact of elements, so its efficiency evaluation may be biased. The non-radial SBM model proposed by Tone [28] effectively solves this problem, but there will be multiple effective elements in the calculation process, and the efficiency value of multiple DMU is 1. Therefore, Tone [29] introduced the super-efficiency SBM model. It complemented the shortcoming that the SBM model cannot distinguish effective DMU by removing the effective units from the production possibility set and measuring the distance to the production front. This cannot only sort the ineffective units but also distinguish effective units. The model is shown in Equation (1), where x and y represent the input and output variables, m and s are the numbers of input and output indicators, and s_i^-, s_r^+ represents the relaxation variables of input and output respectively, whereas λ_j represents the weight vector.

$$
\begin{aligned}
& min\theta = \frac{1+\frac{1}{m}\sum_{i=1}^{m} s_i^- / x_{ik}}{1-\frac{1}{s}\sum_{r=1}^{s} s_r^+ / y_{rk}} \\
& s.t. \quad \sum_{j=1,j\neq k} x_{ij}\lambda_j - s_i^- \leq x_{ik} (i = 1,2,\cdots,m) \\
& \sum_{j-1,j\neq k} y_{rj}\lambda_j + s_r^+ \geq y_k (r = 1,2,\cdots,s) \\
& \lambda_j \geq 0, j = 1,2,\cdots,n(j\neq k), s_i^- \geq 0, s_r^+ \geq 0
\end{aligned}
\tag{1}
$$

2.2. The Malmquist Index Model

Using the super-SBM model, we can effectively evaluate the cross-sectional data of educational efficiency in all countries in the world. However, educational development itself is a dynamic process, including the progress of educational technology and the improvement of educational skills. Therefore, this paper uses the Malmquist index to analyze the dynamic changes in educational efficiency. The Malmquist index can be divided into two parts, catch-up effect and frontier-shift effect [30,31]. The catch-up effect reflects the rate of change effect of DMU relative technical efficiency over time, and the frontier shift reflects the movement of production frontier referenced by the combination of input and output DMUs in the two adjacent periods. Scholars [32] described the Malmquist productivity change index reflecting productivity change measured from t to t + 1 can be expressed by the geometric average of total factor productivity change index (tfpch), as shown in Equation (2),

$$tfpch = M_0\left(x_{t+1}, y_{t+1}, x_t, y_t\right) = \left[\frac{D_0^t\left(x_{t+1}, y_{t+1}\right)}{D_0^t\left(x_t, y_t\right)} \times \frac{D_0^{t+1}\left(x_{t+1}, y_{t+1}\right)}{D_0^{t+1}\left(x_t, y_t\right)}\right]^{1/2} \tag{2}$$

In the analysis of education efficiency, the Malmquist total factor productivity change index can be further decomposed into technical efficiency change index (effch) and technical progress index (techch) [32]. The effch index is the ratio of technical efficiency in phase t+1 and phase t as shown in Equation (3); besides, the techch index is the relative distance between the production frontier in phase t + 1 and phase t, which is the moving distance of the production front, as indicated in Equation (4),

$$effch = \frac{D_0^{t+1}\left(x_{t+1}, y_{t+1}\right)}{D_0^t\left(x_t, y_t\right)} \tag{3}$$

$$techch = \frac{tfpch}{effch} = \left[\frac{D_0^t\left(x_{t+1}, y_{t+1}\right)}{D_0^{t+1}\left(x_{t+1}, y_{t+1}\right)} \times \frac{D_0^t\left(x_t, y_t\right)}{D_0^{t+1}\left(x_t, y_t\right)}\right]^{1/2} \tag{4}$$

Furthermore, the technical efficiency change index (effch) can be decomposed into pure technical efficiency change index (pech) and scale efficiency change index (sech). The pech index is the change of technical efficiency calculated under the condition of variable returns to scale, as shown in Equation (5). The sech index is calculated as the effch under the condition of constant return to scale divided by the pech under the condition of variable return to scale, as presented in Equation (6),

$$pech = \frac{D_0^{t+1}\left(x_{t+1}, y_{t+1}\right)/VRS}{D_0^t\left(x_t, y_t\right)/VRS} \tag{5}$$

$$sech = \frac{effch}{pech} \tag{6}$$

3. Variable Selection and Data Source

An input–output model shows the relationship of those factors going in (input) so that efficient education can yield sustainable national development (output). The values of these educational input–output variables are taken into analysis in the study. In terms of education input, in addition to the traditional variables of total public expenditure on education, this paper also adds variables including total public expenditure per capita on education and the proportion of public expenditure on education in GDP, which can more comprehensively reflect the input of educational resources and proper utilization in a country. In terms of education output, in addition to the variables such as graduation rate, basic education, and higher education achievement that are used in several studies, this paper also employed the Program for International Student Assessment (PISA) scores, the triadic patent families, and other variables, which can not only reflect the educational efficiency in quantity but also reflect the educational efficiency in quality to reduce the deviation caused by the selection of indicators (discussed below).

3.1. Variable Selection

The ideal evaluation of educational efficiency quantifies the educational activities and related factors by constructing and selecting the index system of factors related to educational activities and puts forward corresponding decisions. In recent years, scholars in the field of education have usually measured educational efficiency and improved the efficiency of educational resource allocation by constructing educational input and output indicators based on the internationally developed education indicators of the United Nations Educational, Scientific and Cultural Organization (UNESCO), the World Bank and the Organization for Economic Cooperation and Development (OECD), etc. Moreover, this study also selects the indicators from the perspectives of input and output based on the principles of availability, rationality, and pertinence. The specific indicators are illustrated in Table 2 below.

1. Input variables. (i), the total expenditure on education. It refers to the general expenditure (flow, capital, and transfer) of the government (district, regional, and central authority). It includes expenditures transferred from international funds to the government. The total government expenditure of a certain education level such as primary school, secondary school, higher education, or the sum of all education levels calculated in national currency reflects the total level of education expenditure of various countries. (ii), the total public expenditure on education per capita. It refers to the total expenditure of the government on student education from primary school to the completion/graduation of higher education. Due to different economic levels and population scales of various countries, the total public expenditure on education per capita reflects the level of education investment from an individual aspect. (iii), the proportion of total public expenditure on education in GDP. It reflects the different policies and attention of various countries to the education industry. Through the different proportions of public expenditure on education in GDP, it reflects the differences of input levels among countries in terms of financial resources/budgetary.
2. Output variables. (i), the graduation rate of basic education. This refers to the percentage of students who have completed nine-year compulsory education in the relevant age group, which can reflect the level of basic education in a country; (ii), the achievements of higher education. It refers to the percentage of people who have received college or undergraduate education in the total population, which reflects the level of higher education in a country; (iii), the Program for International Student Assessment (PISA) scores. PISA is a research project on the evaluation of 15-year-old students' reading, mathematics, and science abilities carried out by the OECD [33]. Similarly, PISA assesses how far students near the end of compulsory education have acquired some of the knowledge and skills that are essential for full participation in society. Generally, the domains of reading and mathematical and scientific literacy are not merely covered in terms of mastery of the school curriculum, but in terms of important knowledge and skills needed in adult life [33]. Major countries in the world have participated in the evaluation. PISA can reflect the deficiency of the participant countries' education efficiency according to the international comparison of students' performance in PISA; therefore, this paper uses PISA score data to

evaluate the quality and efficiency of a country's education; (iv), the triadic patent families. A triadic patent family is defined as a set of patents registered in various countries (i.e., patent offices) filed at three of these major patent offices: the European Patent Office (EPO), the Japan Patent Office (JPO), and the United States Patent and Trademark Office (USPTO). Innovation is one of the criteria to measure sustainable development. These patent families can well evaluate various countries' innovation strength and thus reflect the ability of education to sustain development.

Table 2. Input and output index system of education efficiency.

	Variable Descriptions	Variable Units
Education investment index	Total public expenditure on Education	Million dollars
	Total public expenditure on education per capita	Dollar
	Proportion of public expenditure on Education	Percentage of GDP
Education output indicators	Graduation rate of basic education	Percentage of relevant age groups receiving full-time education
	Achievements in Higher Education	Percentage of population with higher education
	PISA score	Test scores of 15-year-old students in reading, mathematics, and science
	Triadic patent families	Quantity

3.2. Data Source

The data of this paper mainly come from the World Bank's education statistics-all indicators database, the UNESCO education database, and the OECD education and patents statistical database. In accordance with the integrity and availability of data, the sample of this paper is selected from 2010 to 2016. After excluding countries with less education input and output, the main countries selected are Argentina, Australia, Austria, Brazil, Canada, Chile, China, Costa Rica, Czech Republic, Finland, France, Germany, Hungary, Ireland, Israel, Italy, Japan, Mexico, Norway, Poland, Portugal, Russia, Slovakia, South Africa, Spain, Sweden, Switzerland, the United Kingdom (UK), and the United States (US).

4. Analysis and Result of Educational Efficiency

4.1. Analysis of Educational Efficiency

To begin, this study adopts DEAP2.1 software to measure and statically analyze the total factor productivity (TFP) of education of the 29 countries by employing the national panel data. The results show that there are many countries with an efficiency value of 1, which is when the DMU is located on the frontier. In order to further effectively analyze the efficiency level of the DMU this paper further employs DEA solver pro5.0 software and adopts the super-SBM model based on input orientation. The detailed results are shown in Table 3 below.

Table 3. Measurement results of education efficiency in major countries in the world from 2010 to 2016.

DMU	2010	2011	2012	2013	2014	2015	2016	Mean	Rank
Argentina	1.1052	1.0396	1.0189	1.0330	1.0446	0.7237	0.8617	0.9752	12
Australia	0.5550	0.6673	0.7662	0.6182	0.6604	0.6990	0.7492	0.6736	18
Austria	0.4917	0.4698	0.4773	0.4923	0.4918	0.5242	0.4482	0.4850	25
Brazil	0.4985	0.4748	0.4722	0.4938	0.5092	0.5469	0.5232	0.5026	24
Canada	0.4317	0.4335	0.4267	0.4568	0.4576	0.4733	0.4473	0.4467	27
Chile	1.2213	1.1907	1.0216	1.0468	1.1332	1.0633	1.0209	1.0997	8
China	1.9954	1.7367	1.5578	1.5512	1.4898	1.4219	1.2858	1.5769	2
Costa Rica	1.3606	1.2964	1.2850	1.2886	1.3865	1.1227	1.0526	1.2561	4
Czech Republic	1.0213	0.7174	0.7470	1.0162	1.0398	0.7464	0.7229	0.8587	15
Finland	0.5737	0.5639	0.5518	0.5668	0.5760	0.6090	0.5569	0.5712	22
France	0.4978	0.4975	0.4792	0.4973	0.4819	0.4854	0.4259	0.4807	26
Germany	0.5839	0.5752	0.6005	0.6269	0.5972	0.6229	0.5696	0.5966	21
Hungary	0.9430	0.9768	1.0973	1.1074	1.0708	1.1186	1.0415	1.0508	10
Ireland	0.6754	0.6744	0.4665	0.6180	0.7799	1.1056	1.0398	0.7657	16
Israel	1.1741	1.1152	1.1705	1.1454	1.1735	1.1610	1.0594	1.1427	6
Italy	0.5502	1.0027	1.0016	0.8609	1.0126	0.8245	0.7669	0.8599	14
Japan	3.2452	3.0264	2.7579	2.3946	3.1131	3.8673	4.5872	3.2845	1
Mexico	0.6448	0.9376	1.0300	1.0218	0.6630	1.0528	1.2171	0.9382	13
Norway	0.3956	0.4007	0.3707	0.4016	0.4226	0.4787	0.4263	0.4137	29
Poland	1.0026	1.0317	1.1100	1.1073	1.1043	1.1575	1.1441	1.0939	9
Portugal	0.5513	0.5472	0.6152	0.6032	0.6621	0.7479	0.6160	0.6204	19
Russia	1.0775	1.0811	1.0971	1.1184	1.0799	1.1196	1.1906	1.1092	7
Slovak Republic	1.3475	1.3873	1.3018	1.3451	1.3208	1.3623	1.6321	1.3853	3
South Africa	1.1116	1.1114	1.1516	1.2625	1.2626	1.3766	1.3323	1.2298	5
Spain	0.4961	0.5011	0.6586	0.7542	0.7710	0.8480	0.6880	0.6739	17
Sweden	0.4508	0.4338	0.4004	0.4138	0.4183	0.4527	0.4189	0.4270	28
Switzerland	1.0148	1.0125	1.0167	1.0588	1.0415	1.0392	1.0210	1.0292	11
United Kingdom	0.5247	0.5311	0.5563	0.6020	0.5708	0.5337	0.5309	0.5499	23
United States	0.6038	0.6163	0.6230	0.6736	0.6082	0.5733	0.4922	0.5986	20
Mean	0.9015	0.8983	0.8907	0.9026	0.9291	0.9606	0.9610	0.9205	

In terms of years, the average educational efficiencies of the investigated countries from 2010 to 2016 were 0.9015, 0.8983, 0.8907, 0.9026, 0.9291, 0.9606, and 0.9610, respectively. It can be observed that the efficiency values over the years were less than 1. The overall educational efficiency was in the DEA ineffective state, indicating that the utilization rate of educational investment factors in the studied countries was not high enough and the allocation of educational resources was not reasonable. Except for 2011 and 2012, the educational efficiency in the mentioned countries had been gradually improved, and in 2016, which was very close to the production frontier, indicates that the utilization rate of educational input factors and the allocation of educational resources were exceptionally effective.

In terms of countries, the countries with the highest educational efficiency are Japan, China, Slovakia, Costa Rica, South Africa, Israel, Russia, Chile, Poland, Hungary, and Switzerland. The average educational efficiency of these countries during the study period was greater than 1, indicating that these countries had been basically achieved DEA efficiency. Nevertheless, Argentina, Mexico, Italy, the Czech Republic, Ireland, Spain, Australia, Portugal, the US, Germany, Finland, the UK, Brazil, Austria, France, Canada, Sweden, and Norway had been an average educational efficiency of less than 1, which was in a DEA ineffective state. It can be seen that education efficiency in some developing economic countries has been either equal or better than some developed countries, which demonstrates that they have made considerable strides in realizing education for development, rapidly building a quality and efficient education system for their society. To support the result of this study, Xu and Liu [4] found that the countries with considerable efficiency progress in education and technology were primarily concentrated in East Asia, specifically Japan and China. Not to mention that the quality and efficiency of higher education are necessary to achieve massive human capital. Besides, efficient education conveys sustainable endogenous economic development and boosts technology progress [3].

There are two main reasons for the high educational efficiency in these developing economic countries. First is the educational policy reform advantage. For instance, countries like China and South Africa are in the early stage of economic development and their educational development was mainly focused on elementary education. In recent years, with the improvement of economic development and the transformation of educational policies, the facilities of higher education in these countries have been developed rapidly [34,35]. Accordingly, compared with other countries, it has a certain scale advantage, resulting in higher marginal efficiency. Second, there are certain late development advantages. Education in developing economic countries started relatively late [8]. By learning from the experience of advanced economic countries the layout of educational input and output became relatively efficient and established effective government regulations, which is conducive to the effective allocation of educational resources [34,35].

Compared with developing economic countries, most of the western countries that are investigated in this study have basically completed the popularization of compulsory education and higher education earlier. However, this study result demonstrates that most of these countries have had lower education efficiency due to, inter alia, the allocation of educational resources perhaps not optimized in time, which leads to the waste of educational input resources and the reduction of expenditure efficiency, followed by the inevitable decline of educational efficiency. Therefore, with the increase of the budget and investment in education sectors, the overall scale of educational efficiency could be increased but there are also obvious competitive effects and spatial spillover characteristics that need to be taken into consideration, including policy formulation, operation efficiency, technological strategies, and policy sustainability.

Incidentally, according to the results of educational efficiency value, this paper classified the studied countries into three levels, such as countries with $p \geq 1$ value as high educational efficiency, countries with 1

> $p \geq 0.5$ value as medium educational efficiency, and countries with $p < 0.5$ value as low educational efficiency. The number of countries included in each education efficiency interval is shown in Table 4 below. It can be seen that the education efficiency of most of the studied countries has been mainly medium and high education efficiency. Similarly, the trend of transformation from low-efficiency countries to medium-high efficiency countries has been lingering, indicating that the overall efficiency improvement rate has been slow.

Table 4. The number of countries in each education efficiency interval.

	2010	2011	2012	2013	2014	2015	2016	Mean
Number of countries with high educational efficiency	12	12	14	14	13	13	13	13
Number of countries with middle educational efficiency	11	11	8	10	12	12	10	11
Number of countries with low educational efficiency	6	6	7	5	4	4	6	5

Furthermore, according to the average efficiency over the years this paper ranked the educational efficiency of the studied countries, and the results are demonstrated in Figure 1 below. During the study period, hierarchically, countries from Japan to Switzerland are ranked high in educational efficiency. Similarly, countries from Argentina to Brazil are ranked middle education efficiency countries, whereas countries from Austria to Norway are low education efficiency countries. Apparently, it is not difficult to see that there are huge differences between high and low education efficiency countries, and the average difference of the highest education efficiency was 2.8708. This indicates that there were huge differences in the level of education efficiency among the 29 countries, and reveals that the development of education level in the world has been absolutely unbalanced (See Figure 1).

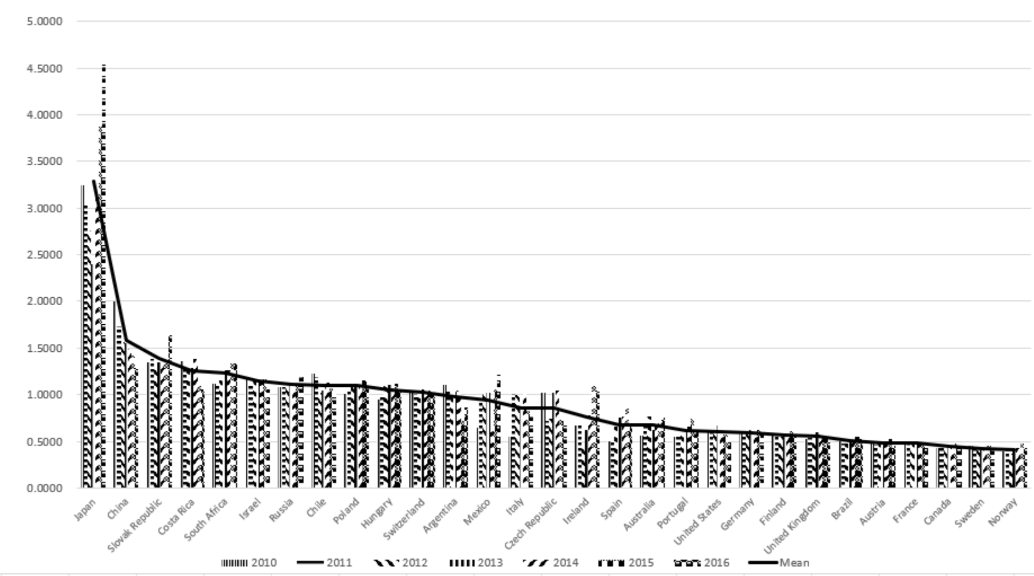

Figure 1. Education efficiency values and average values of education efficiency in the investigated countries over the sample period.

4.2. Assessment Result of Educational Efficiency in the World's Major Economies

With the acceleration of globalization, some economic countries, especially world economic powers, have an increasing impact on the overall education efficiency of the world. On account of this fact, this section precisely compares the education efficiency of nine world economies, such as the US, China, Japan, Germany, the UK, France, Italy, Brazil, and Canada aiming to clarify their education efficiency level and the driving factors (see Figure 2).

As can be seen from the above figure, Japan's educational efficiency leads and China follows. This denotes that Japan's educational efficiency was at the forefront of technology and the main driving country in educational efficiency. Comparatively, although the educational efficiency value of China has been declining during the research period, the overall efficiency value was greater than 1, indicating that China was also one of the driving countries in educational efficiency, but its impact has been gradually decreasing due to various reasons [36]. According to the analyzed result, the educational efficiencies of the US, Germany, the UK, France, Canada, and Brazil were less than 1. This implies that the educational efficiency of these countries had been in a DEA ineffective state during the research period. However, it is worth noting that the low level of educational efficiency does not mean that the educational strength was low because the DEA method measures relative efficiency. The low-efficiency value only indicates that these countries have considerable deficiencies in the utilization level of educational resources and relatively low substantial investment in human capital [37]. It is assumed that the US, the UK, Germany, and France are still countries with traditionally high educational strength. However, Brazil is quite different from these countries. It is not considered as one of the traditional educational power countries, but its educational efficiency value was also low. This demonstrates that there is a significant gap in this country and concurrently implies a direction for future research. Differently, Italy's education efficiency fluctuated significantly during the study period, and the DEA value was effective in 2011, 2012, and 2014, but on the overall level, its DEA value was still ineffective.

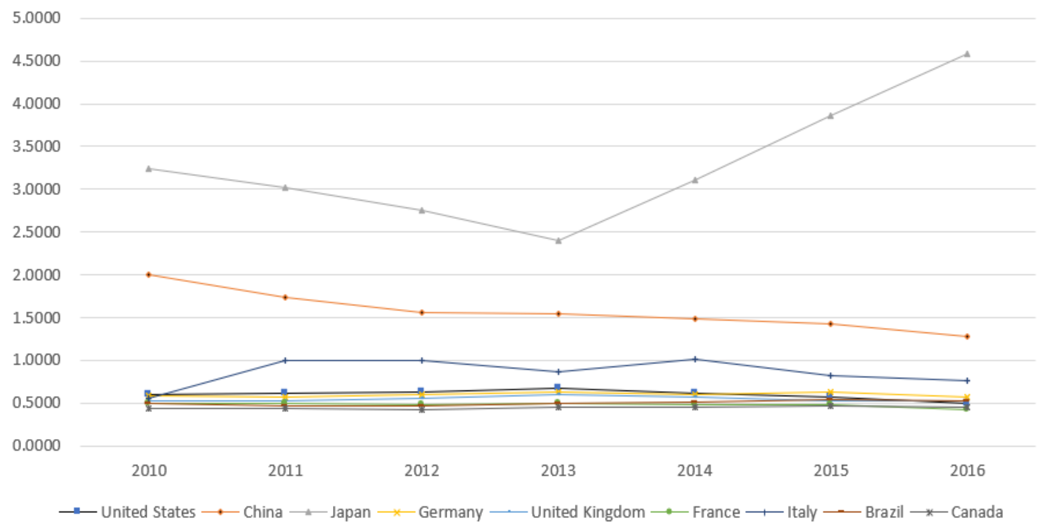

Figure 2. Assessment results of education efficiency of the world's major economies from 2010 to 2016.

4.3. Decomposition Results of Malmquist Total Factor Productivity (TFP) Index

In order to further clarify the sustainable development of educational efficiency in major countries across the world and analyze the factors affecting educational efficiency, the Malmquist TFP index based on the DEA method provides a convenient tool for analyzing the changes in educational efficiency of all elements of education in various countries. Based on this method, this section analyzes the changes and decomposition results of the TFP of education in major countries in the world from 2010 to 2016, as presented in Table 5.

Table 5. Changes and decomposition of the Malmquist index of overall education efficiency in major countries in the world from 2010 to 2016.

Year	effch	techch	pech	sech	tfpch
2010–2011	1.014	0.980	1.002	1.012	0.994
2011–2012	0.982	1.003	0.998	0.984	0.985
2012–2013	1.002	0.986	0.984	1.019	0.988
2013–2014	1.002	1.015	1.003	0.999	1.017
2014–2015	1.000	1.020	1.003	0.997	1.020
2015–2016	0.986	1.034	0.982	1.005	1.020
Mean	0.998	1.006	0.995	1.003	1.004

From the perspective of time series, the overall education TFP index of major countries in the world shows a downward trend first and then an upward trend. The trend of technological progress change index (techch) is basically consistent with the trend of education total factor productivity change index (tfpch), indicating that technological progress directly affects the sustainability of educational efficiency. Similarly, the scale efficiency change index (sech) can promote education TFP, whereas the technical efficiency change index (effch), especially the pure technical efficiency change index (pfch), can subdue the tfpch of education. Generally, the growth rate of education TFP has been reduced in 2010–2011, 2011–2012, and 2012–2013, of which in 2011–2012 was the highest decline, which was 1.5%. The growth rate of the education TFP index in 2013–2014, 2014–2015, and 2015–2016 was increased, of which the growth rate in 2014–2015 and 2015–2016 was comparatively the highest (2.0%.). As for the factors causing the change of the education TFP index, there are differences among the sample period. To illustrate, from 2010 to 2011 and 2012–2013, the decline of the tfpch index was mainly due to the decline of the techch index, whereas from 2011 to 2012, the tfpch index was mainly due to the decline of the effch index. At the same time, the increases of the tfpch index in 2013–2014, 2014–2015, and 2015–2016 were mainly due to the rise of the techch index.

From an overall perspective, the average annual tfpch index of education in the studied countries was greater than 1, with an average annual growth of 0.4%, indicating that the overall level of education efficiency in the world has been on the rise, but the rise was relatively slow, which is consistent with the conclusion that the education efficiency of investigated countries has been gradually improving from the previous static analysis. By further decomposing the tfpch index, it is found that the mean value of the techch was 1.006, indicating that technological progress has been the main factor leading to the growth of TFP of education, and technical efficiency inhibited the growth of TFP of education. Moreover, technical efficiency can be decomposed into the product of pure technical efficiency and scale efficiency. The pech index was less than 1 and the sech index was greater than 1, which further denotes that pech index inhibits the growth of educational TFP, but scale efficiency plays a certain role in promoting educational TFP. Specifically, during the study period, the improvement of educational technology level and scale efficiency in the analyzed countries improved the frontier of educational productions, and the production function curve moved upward. Apparently, the allocation and management level of educational resources restricts the development of educational efficiency [38–40]. Therefore, while paying considerable attention to the improvement of educational technology, educational authorities must scientifically adjust the allocation of educational resources, increase investment in human capital, and ensure the enhancement of educational efficiency and effectiveness as well as the improvement of management skills.

Table 6. Changes and decomposition of the Malmquist index of education efficiency in major countries in the world from 2010 to 2016.

Country	effch	techch	pech	sech	tfpch
Argentina	0.991	0.993	0.996	0.995	0.984
Australia	1.010	1.022	1.000	1.010	1.032
Austria	0.969	1.034	0.938	1.033	1.002
Brazil	1.040	0.990	1.019	1.021	1.029
Canada	0.987	1.007	0.984	1.003	0.993
Chile	1.000	0.960	1.000	1.000	0.960
China	1.000	0.941	1.000	1.000	0.941
Costa Rica	1.000	0.946	1.000	1.000	0.946
Czech Republic	0.980	0.994	1.000	0.980	0.974
Finland	0.980	1.012	1.000	0.980	0.992
France	0.982	1.008	0.979	1.003	0.990
Germany	0.995	1.019	0.998	0.997	1.015
Hungary	1.005	0.988	1.000	1.005	0.993
Ireland	1.021	1.020	1.000	1.021	1.041
Israel	1.000	0.989	1.000	1.000	0.989
Italy	1.013	1.007	1.000	1.013	1.020
Japan	1.000	1.025	1.000	1.000	1.025
Mexico	1.029	1.010	1.021	1.008	1.039
Norway	0.978	1.018	0.981	0.997	0.996
Poland	1.000	1.028	1.000	1.000	1.028
Portugal	1.002	1.008	0.993	1.009	1.010
Russia	1.000	1.017	1.000	1.000	1.017
Slovak Republic	1.000	1.004	1.000	1.000	1.004
South Africa	1.000	1.025	1.000	1.000	1.025
Spain	1.021	1.019	1.019	1.002	1.040
Sweden	0.965	1.016	0.943	1.023	0.980
Switzerland	1.000	1.016	1.000	1.000	1.016
United Kingdom	0.989	1.033	0.992	0.996	1.022

United States	0.981	1.041	1.000	0.981	1.021
Mean	0.998	1.006	0.995	1.003	1.004

Furthermore, as the Malmquist index in table 6 indicates, there were 17 countries whose average tfpch index was greater than 1 during the study period, namely Australia, Austria, Brazil, Germany, Ireland, Italy, Japan, Mexico, Poland, Portugal, Russia, Slovakia, South Africa, Spain, Switzerland, the UK, and the US. It shows that the overall TFP of education in these countries has been increasing. Comparatively speaking, among the 29 countries, Ireland ranked first with a 1.041 average value of TFP. Simultaneously, it can be seen that the average values of effch index, techch index, pech index, sech index, and tfpch index of Ireland was greater than 1, which indicates that the overall efficiency of education input–output in Ireland was exceptional. The main reasons for the growth of TFP of education in Ireland could be the improvement of technological progress and technological efficiency among others. Technological efficiency can be decomposed into the product of pure technological efficiency and scale efficiency, while its pech index was 1, which has not been changed, and the sech index was 1.021. Therefore, we can conclude that the improvement of technological efficiency mainly comes from the improvement of scale efficiency.

Contrarily, those countries whose average value of the tfpch index was less than 1, discloses that the TFP of education in these countries showed a downward trend and needed to be improved. Among them, the most obvious decline was in China and Costa Rica, where the average TFP of education decreased by 5.9% and 5.4% respectively. From the results of the tfpch index decomposition, techch index showed a downward trend and decreased by 5.9%, whereas effch index, sech index, and pech index did not change, implying that the decline of the techch index was the main reason for the decline of China's TFP of education. The situation in Costa Rica was somewhat similar to that of China.

To summarize, this study discovered that technological progress is the primary factor leading to the growth and development of TFP of education in a given country [4]. Similarly, scale efficiency also plays a certain role in promoting the TFP of education, whereas technical efficiency, especially pure technical efficiency, plays a restraining role [41]. Therefore, for any country in the world, the key to improving educational efficiency is to advance the level of educational technology. How to improve the level of educational technology is directly related to whether the total factor productivity of education can be further improved. At the same time, we also need to pay significant attention to technical efficiency and scientifically adjust the allocation of educational resources, improve the level of educational resource management and the scale of technology-related as well as innovative approach educations.

5. Conclusions

Nowadays, there is much scrutiny on the quality and efficiency of education due to the rising issue of public concern for increasing public expenditure on education in the face of the low moral standard of graduates, inadequate public services, increasingly low self-esteem, highly unsatisfactory scholastic performance, and escalation of national unemployment rate questioning the relevance of education at all levels. Consequently, this paper empirically assesses and compares the educational efficiency across developed and developing economic countries in an effort to discover the problems existing in the utilization of educational resources, the causes of low efficiency in education, and the significance of investment in the education sector.

This paper constructed the education input–output index by using the national-level panel data of 29 major countries across the world, and assesses and analyzes the education efficiency of these countries by using the super-SBM model and the Malmquist index. Hence, the analysis and assessment of this paper can be summarized as follows.

(1) From the static analysis results, the overall education efficiency of the studied countries was in the DEA ineffective state. Except for 2011 and 2012, the education efficiency was gradually improving during the study period. Similarly, the educational efficiency of analyzed countries was mainly medium and high educational efficiency during the study period. In terms of years, the trend of transformation from low-efficiency countries to medium-high efficiency countries was slow. In addition, while ranking the educational efficiency of various countries based on the study result of the average efficiency over the years, this study observed that in addition to some developed countries, the educational efficiency of a number of developing countries was also at the forefront of technology. This study also discovered that there are huge differences in the level of educational efficiency among the investigated countries, and the development of the world educational level was quite unbalanced.

(2) From the dynamic analysis results at the time series level, the overall education TPF index of major countries in the world shows a downward trend first and then an upward trend. The trend of techch was basically consistent with the trend of tfpch, and the pech and sech have also had varying degrees of impact on the education TPF index. Similarly, the average annual education of the investigated countries' tfpch index was greater than 1 with an average annual growth of 0.4%, which demonstrated that the overall level of education efficiency shows an upward trend; however, the upward range has been relatively slow. The study discovers that technological progress was the main factor to promote the growth of education total factor productivity [42]. Moreover, during the study period, there were 17 countries with a mean value of the tfpch index greater than 1, which signifies that the overall TFP of education in these countries has been increasing. In particular, the mean value of Ireland's TFP was 1.041, ranked first among 29 countries. Technical efficiency and technological progress were the major reasons for the increment of Ireland's TFP. Except for the above 17 countries, the average tfpch index of other countries was less than 1, which discloses that the TFP of education in these countries had a downward trend and required improvement. Among them, China and Costa Rica have a large decline, with an average annual decline of 5.9% and 5.4% respectively. The decline of the techch index could be the primary reason for the decline of efficiency of education in these countries [4].

To conclude, with the increasing investment of educational resources in various countries, the level of educational efficiency was improving, but the growth rate is relatively slow. In addition to Japan, Slovakia, Israel, Hungary, Switzerland, and other developed countries, some old-developed countries, such as the UK and US, due to the constraints brought by the high development of its education level, showed that the overall educational efficiency was in a DEA ineffective state. Therefore, these countries can improve it by learning from the educational development model of Japan and other developed countries. Although some developing countries, such as China have basically achieved DEA effectiveness by increasing budgetary in educational resources, educational efficiency, and TFP of education had been dramatically decreased during the study period and improvement was greatly required.

This study observed that educational technological progress was the leading factor influencing the improvement of educational TFP in the studied countries. Moreover, according to the theory of efficiency and productivity, the high contribution rate of technological progress to TFP in the education sector generally occurs only when the country enters the mature period of development [43–45]. Consequently, these countries need to constantly optimize their educational resource allocation structure, strengthen the integration of resource stock, and adopt the shared resource model to optimize the utilization efficiency of existing resources. Simultaneously, in order to attain a sustainable educational efficiency and educational productivity, countries must strengthen the overall management of the educational sector, establish a resource integration mechanism, compose a set of top-down responsibility and special education resource integration guarantee mechanisms, create a policy control for the flow of educational financial resources, and maximize educational resource stocks.

Once the external and internal government strategies ensure that educational agencies and institutes are vibrant, inputs are enabling, outputs are examined, legal frameworks are in place, and the processes are expeditiously effective; thus, the following outcomes can be expected including professionalism will be increased, the knowledge gap will be bridged, national economic development will be sustained, and international competitiveness will be enhanced. The degree of sustainable development is closely related to the comprehensive quality of education in society. The government of the country can promote the level of educational modernization by increasing the investment in educational technology, investment in research and development (R&D), improving competency-based learning, enhancing knowledge-intensive services, and actively changing the talent training mode in coordination with the concept of "innovation" [46]. In addition, effectively improving the professional level of teachers, increasing educational output with technological progress, and integrating innovation with the education system are also equally important [44,45]. Apparently, a country's innovation strategies must coordinate disparate policies toward scientific research, information technology investments, technology commercialization, and education development. Thus, these cumulative efforts could guide quality and efficiency in the education sectors in the country.

Author Contributions: Conceptualization, Y.Y.; methodology L.C. and Y.Y.; software L.C.; validation, L.C., A.K.A., and Y.Y.; formal analysis, Y.Y., L.C., A.K.A., and X.G.; investigation, L.C. and A.K.A.; resources, L.C., A.K.A., Y.Y., and X.G.; data curation L.C. and X.G.; writing—original draft preparation, L.C. and Y.Y.; writing—review and editing, Y.Y. and A.K.A.; visualization, L.C. and A.K.A.; supervision, Y.Y.; project administration, Y.Y.; funding acquisition, Y.Y. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Education Project for Youth of National Social Science Fund of China, grant number CGA180247. We would like to show gratitude for their research funding support.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Our study did not report any data.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

References

1. Asongu, S.A.; Diop, S.; Addis, A.K. Governance, Inequality and Inclusive Education in Sub-Saharan Africa. *Forum Soc. Econ.* **2020**, Forthcoming, 1–25. https://doi.org/10.1080/07360932.2020.1856166.
2. Chytilova, H. The Causal Impact of Economic Education on Achievement of Optimum Outcomes. *Procedia-Soc. Behav. Sci.* **2013**, *106*, 2628–2635. https://doi.org/10.1016/j.sbspro.2013.12.303.
3. Ozturk, I. The Role of Education in Economic Development: A Theoretical Perspective. *SSRN Electron. J.* **2008**, *XXXIII*, 39–47. https://doi.org/10.2139/ssrn.1137541.
4. Xu, H.; Liu, F. Measuring the Efficiency of Education and Technology via DEA Approach: Implications on National Development. *Soc. Sci.* **2017**, *6*, 136.
5. Sahnoun, M.; Abdennadher, C. Returns to investment in education in the OECD countries: Does governance quality matter? *J. Knowl. Econ.* **2021**, Forthcoming, 1–24. https://doi.org/10.1007/s13132-021-00783-0.
6. Wolf, F.; Zohlnhöfer, R. Investing in human capital? The determinants of private education expenditure in 26 OECD countries. *J. Eur. Soc. Policy* **2009**, *19*, 230–244. https://doi.org/10.1177/0958928709104738.
7. Griffore, R.J.; Phenice, L.A.; Hsieh, M.-C. Trend Analysis of Educational Investments and Outcomes. *J. Res. Educ.* **2014**, *24*, 154–161.
8. Miningou, E.W. *Quality Education and the Efficiency of Public Expenditure: A Cross-Country Comparative Analysis*; World Bank: Washington, DC, USA, 2019.
9. Ross, P.H. Occupation Aspirations, Education Investment, and Cognitive Outcomes: Evidence from Indian Adolescents. *World Dev.* **2019**, *123*, 104613. https://doi.org/10.1016/j.worlddev.2019.104613.
10. Coleman, J.S. *Equality of Educational Opportunity*; U.S. Department of Health, Education, and Welfare, Office of Education: Washington, DC, USA, 1966.
11. De Witte, K.; López-Torres, L. Efficiency in education: A review of literature and a way forward. *J. Oper. Res. Soc.* **2017**, *68*, 339–363. https://doi.org/10.1057/jors.2015.92.
12. Titus, M.A.; Eagan, K. Examining Production Efficiency in Higher Education: The Utility of Stochastic Frontier Analysis. In *Higher Education: Handbook of Theory and Research*; Paulsen, M.B., Ed.; Springer International Publishing: Cham, Germany, 2016; pp. 441–512.
13. Rządziński, L.; Sworowska, A. Parametric and Non Parametric Methods for Efficiency Assessment of State Higher Vocational Schools in 2009–2011. *Entrep. Bus. Econ. Rev.* **2016**, *4*, 95–112. https://doi.org/10.15678/EBER.2016.040107.
14. Izadi, H.; Johnes, G.; Oskrochi, R.; Crouchley, R. Stochastic Frontier Estimation of a CES Cost Function: The Case of Higher Education in Britain. *Econ. Educ. Rev.* **2002**, *21*, 63–71. https://doi.org/10.1016/S0272-7757(00)00044-3.
15. Johnes, J. Data Envelopment Analysis and Its Application to the Measurement of Efficiency in Higher Education. *Econ. Educ. Rev.* **2006**, *25*, 273–288. https://doi.org/10.1016/j.econedurev.2005.02.005.

16. Sibiano, P.; Agasisti, T. Efficiency of Public Spending in Education: A Challenge among Italian Regions. In *Investigaciones de Economía de la Educación Volume 6*; Caparrós Ruiz, A., Ed.; Asociación de Economía de la Educación: Zaragoza, Spain : **2011**; pp. 503–516, Volume 6.
17. Sibiano, P.; Agasisti, T. Efficiency and Heterogeneity of Public Spending in Education among Italian Regions. *J. Public Aff.* **2013**, *13*, 12–22. https://doi.org/10.1002/pa.1404.
18. Dincă, M.S.; Dincă, G.; Andronic, M.L.; Pasztori, A.M. Assessment of the European Union's Educational Efficiency. *Sustainability* **2021**, *13*, 3116. https://doi.org/10.3390/su13063116.
19. Johnes, J.; Yu, L. Measuring the Research Performance of Chinese Higher Education Institutions Using Data Envelopment Analysis. *China Econ. Rev.* **2008**, *19*, 679–696. https://doi.org/10.1016/j.chieco.2008.08.004.
20. Guccio, C.; Martorana, M.F.; Monaco, L. Evaluating the Impact of the Bologna Process on the Efficiency Convergence of Italian Universities: A Non-Parametric Frontier Approach. *J. Prod. Anal.* **2016**, *45*, 275–298. https://doi.org/10.1007/s11123-015-0459-6.
21. Başkaya, S.; Klumpp, M. International Data Envelopment Analysis in Higher Education: How Do Institutional Factors Influence University Efficiency? *J. Bus. Econ.* **2014**, *5*, 2085–2090. https://doi.org/10.15341/jbe(2155-7950)/11.05.2014/013.
22. Yalçin, S.; Tavşancil, E. The Comparison of Turkish Students' PISA Achievement Levels by Year via Data Envelopment Analysis. *Educ. Sci. Theory Pr.* **2014**, *14*, 961–968.
23. Al-Bagoury, S. Dea to Evaluate Efficiency of African Higher Education. *Educ. Res. Essays* **2013**, *3*, 742–747.
24. McMahon, W. The external social benefits of higher education: Theory, evidence, and policy implications. *J. Educ. Financ.* **2021**, *46*, 398.
25. Ji, Y.-B.; Lee, C. Data Envelopment Analysis. *Stata J.* **2010**, *10*, 267–280. https://doi.org/10.1177/1536867x1001000207.
26. Martín-Gamboa, M.; Iribarren, D. Coupled Life Cycle Thinking and Data Envelopment Analysis for Quantitative Sustainability Improvement. In *Methods in Sustainability Science*; Ren, J., Ed.; Elsevier: Amsterdam, The Netherlands, **2021**; pp. 295–320.
27. Cova-Alonso, D.J.; Díaz-Hernández, J.J.; Martínez-Budría, E. A strong efficiency measure for CCR/BCC models. *Eur. J. Oper. Res.* **2020**, *291*, 284–295. https://doi.org/10.1016/j.ejor.2020.09.006.
28. Tone, K. A Slacks-Based Measure of Efficiency in Data Envelopment Analysis. *Eur. J. Oper. Res.* **2001**, *130*, 498–509. https://doi.org/10.1016/s0377-2217(99)00407-5.
29. Tone, K. A Slacks-Based Measure of Super-Efficiency in Data Envelopment Analysis. *Eur. J. Oper. Res.* **2002**, *143*, 32–41. https://doi.org/10.1016/s0377-2217(01)00324-1.
30. Coelli, T.; Rao, D.S.P.; Battese, G.E. *An Introduction to Efficiency and Productivity Analysis*; Springer: Boston, MA, USA, **1997**.
31. Malmquist, S. Index Numbers and Indifference Surfaces. *Trab. Estad.* **1953**, *4*, 209–242. https://doi.org/10.1007/bf03006863.
32. Färe, R.; Grosskopf, S.; Margaritis, D. Malmquist Productivity Indexes and DEA. In *Handbook on Data Envelopment Analysis*. *International Series in Operations Research & Management Science*; Cooper, W.W., Seiford, L.M., Zhu, J., Eds.; Springer: Boston, MA, USA, **2011**; Volume 164, pp. 127–149.

33. OECD. *21st-Century Readers: Developing Literacy Skills in a Digital World*; OECD Publishing: Paris, France, **2021**.
34. Chen, K.; Zhu, K.; Xu, J.; Meng, M. Sustainable development education from the perspective of China. In Proceedings of the Proceedings of the 2019 4th International Conference on Information and Education Innovations—ICIEI 2019, Durham, UK, 10–12 July **2019**; pp. 105–108. https://doi.org/10.1145/3345094.3345108.
35. Olivier, J.; Kruger, D. Science Education in South Africa. In *Science Education in Countries Along the Belt & Road: Future Insights and New Requirements*; Huang, R., Xin, B., Tlili, A., Yang, F., Zhang, X., Zhu, L., Jemni, M., Eds.; Springer: Berlin/Heidelberg, Germany, **2022**; pp. 185–203. https://doi.org/10.1007/978-981-16-6955-2_12.
36. Xue, W.; Li, H.; Ali, R.; Rehman, R.; Fernández-Sánchez, G. Assessing the static and dynamic efficiency of scientific research of HEIs China: Three stage dea–malmquist index approach. *Sustainability* **2021**, *13*, 8207. https://doi.org/10.3390/su13158207.
37. Bacovic, M.; Andrijasevic, Z.; Pejovic, B. STEM Education and Growth in Europe. *J. Knowl. Econ.* **2021**, Forthcoming. https://doi.org/10.1007/s13132-021-00817-7.
38. Abayasekara, A.; Arunatilake, N. School-Level Resource Allocation and Education Outcomes in Sri Lanka. *Int. J. Educ. Dev.* **2018**, *61*, 127–141. https://doi.org/10.1016/j.ijedudev.2017.12.010.
39. BenDavid-Hadar, I. Funding Education: Developing a Method of Allocation for Improvement. *Int. J. Educ. Manag.* **2018**, *32*, 2–26. https://doi.org/10.1108/ijem-07-2016-0161.
40. Cheng, S.; Zhou, Y. The Evaluation and Optimization to the Higher Educational Resource Allocation. *Int. J. Cogn. Inform. Nat. Intell.* **2015**, *9*, 60–73. https://doi.org/10.4018/ijcini.2015010105.
41. Liang, L.; Wang, Z.B.; Luo, D.; Wei, Y.; Sun, J. Synergy effects and it's influencing factors of China's high technological innovation and regional economy. *PLoS ONE* **2020**, *15*, e0231335. https://doi.org/10.1371/journal.pone.0231335.
42. Song, M.; Peng, L.; Shang, Y.; Zhao, X. Green technology progress and total factor productivity of resource-based enterprises: A perspective of technical compensation of environmental regulation. *Technol. Forecast. Soc. Chang.* **2021**, *174*, 121276. https://doi.org/10.1016/j.techfore.2021.121276.
43. Aristovnik, A. The Impact of ICT on Educational Performance and Its Efficiency in Selected EU and OECD Countries: A Non-Parametric Analysis. *SSRN Electron. J.* **2012**, *11*, 144–152. https://doi.org/10.2139/ssrn.2187482.
44. Ghavifekr, S.; Rosdy, W.A.W. Teaching and Learning with Technology: Effectiveness of ICT Integration in Schools. *Int. J. Res. Educ. Sci.* **2015**, *1*, 175. https://doi.org/10.21890/ijres.23596.
45. Johnes, J.; Portela, M.; Thanassoulis, E. Efficiency in education. *J. Oper. Res. Soc.* **2017**, *68*, 331–338. https://doi.org/10.1057/s41274-016-0109-z.
46. Maradana, R.P.; Pradhan, R.P.; Dash, S.; Gaurav, K.; Jayakumar, M.; Chatterjee, D. Does innovation promote economic growth? Evidence from European countries. *J. Innov. Entrep.* **2017**, *6*, 1. https://doi.org/10.1186/s13731-016-0061-9.