SUSTAINABLE DEVELOPMENT IN EDUCATION: A NON-PARAMETRIC ANALYSIS

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Abstract

The SDGs (Sustainable Development Goals) are a universal call to action to end poverty, protect the planet and improve the lives and prospects of everyone, everywhere. In 2015 all UN Member States, adopted the 2030 Agenda for the SDG, which comprises an action plan for people, the planet and prosperity with 17 objectives covering the economic, social and environmental dimensions, [1]. SDG 4 is the goal of quality education with made up of 10 targets to ensure an inclusive and equitable quality education and to promote lifelong learning opportunities for all. In this sense, it is expected that all countries increasing the number of young people and adults with relevant professional skills, decent jobs, entrepreneurship, eliminating gender and income disparities in access to education.

This article examines the quality of education in 17 European countries using a model nonparametric deterministic for measuring efficiency based on Data Envelopment Analysis (DEA) [2], in combination with other mathematical techniques (such as accumulated effort and group indicator), during seven years (every three years from 2000-2018). To this end, we analyze the countries evolution at three distinct efficiency stages: levels, patterns and determinants. The study is based on the EU's set of indicators to monitor progress towards the UN SDGs: basic education (early leavers from education and training, participation in early childhood education and achievement in reading, mathematic or science), tertiary education (tertiary education attainment and employment rates of recent graduates) and adult learning (adult participation in learning).

This study allows us to address questions such as: To what extent are European countries improving education quality? Which European countries have significant advances / setbacks over time? What factors are intervening in the process of the countries that are most efficient and least efficient? In other words, our results clarify which are the profiles of the countries that are most efficient, giving some insight about the improvements which could be applied in the less efficient to raise their efficiency, in view of reaching the proposed objectives for the year 2030.

Keywords: Multidirectional Efficiency Analysis, Quality education, Sustainable Development Goals.

1. INTRODUCTION

A total of 193 countries in the world have promised to improve the planet and the lives of its citizens by 2030 with 17 life-changing goals, outlined by the UN in September 2015. These Global Goals, also known as the Sustainable Development Goals (SDGs), are a call for action by all countries to promote prosperity while protecting the planet. In this sense, ending poverty must go hand-in-hand with strategies that build economic growth and address a range of social needs (education, health, social protection, and job opportunities) while tackling climate change and environmental protection, [1].

The Sustainable Development Goal indicators comprises important aspects in the human being and determinants in an equitable society see [1]: Goal 1. End poverty in all its forms everywhere. Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture. Goal 3: Ensure healthy lives and promote well-being for all at all ages. Goal 4: Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all. Goal 5: Achieve gender equality and empower all women and girls. Goal 6: Ensure availability and sustainable management of water and sanitation for all. Goal 7: Ensure access to affordable, reliable, sustainable, and modern energy for all. Goal 8: Promote sustained, inclusive, and sustainable economic growth, full and productive employment and decent work for all. Goal 9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation. Goal 10: Reduce inequality within and among countries. Goal 11: Make cities and

human settlements inclusive, safe, resilient and sustainable. Goal 12: Ensure sustainable consumption and production patterns. Goal 13: Take urgent action to combat climate change and its impacts. Goal 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development. Goal 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss. Goal 16: Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels. Goal 17: Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development.

Figure 1. United Nations Sustainable Development Goals. From the UN Website.

We are interested in the study of the country's evolution about the Goal 4, which determines specifically: (4.1) By 2030, ensure that all girls and boys complete free, equitable and quality primary and secondary education leading to relevant and effective learning outcomes. (4.2) By 2030, ensure that all girls and boys have access to quality early childhood development, care, and preprimary education so that they are ready for primary education. (4.3) By 2030, ensure equal access for all women and men to affordable and quality technical, vocational, and tertiary education, including university. (4.4) By 2030, substantially increase the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs, and entrepreneurship. (4.5) By 2030, eliminate gender disparities in education and ensure equal access to all levels of education and vocational training for the vulnerable, including persons with disabilities, indigenous peoples, and children in vulnerable situations. (4.6) By 2030, ensure that all youth and a substantial proportion of adults, both men and women, achieve literacy and numeracy. (4.7) By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship, and appreciation of cultural diversity and of culture's contribution to sustainable development. (4.a) Build and upgrade education facilities that are child, disability and gender sensitive and provide safe, nonviolent, inclusive and effective learning environments for all. (4.b) By 2020, substantially expand globally the number of scholarships available to developing countries, in particular least developed countries, small island developing States and African countries, for enrolment in higher education, including vocational training and information and communications technology, technical, engineering and scientific programmes, in developed countries and other developing countries, see [1].

This paper examines the quality of education, with a view to achieving Goal 4 (ensuring inclusive and equitable quality education and promoting lifelong learning opportunities for all) in 17 European countries: BE (Belgium); CZ (Czechia); DK (Denmark); DE (Germany); IE (Ireland); EL (Greece); FR (France); IT (Italy); LV (Latvia); LU (Luxembourg); HU (Hungary); PL (Poland); PT (Portugal); FI (Finland); SE (Sweden); IS (Iceland) and CH (Switzerland). The analysis is made according to the indicators to monitor progress towards the UN SDGs (Table 1) and the study period is formed by the seven years: 2006, 2009, 2012, 2015 and 2018. The main reason for selecting this set of years, is because, it is important to know in what measure the strategies implemented by each country works. Then, the study considers not only the years after the proposal (2015 and 2018); but also, years prior to this (2006, 2009 and 2012). In this way it is possible to assess the real difference in the strategies adopted by the countries, before and after the SDGs.

In general terms the relative efficiency of a Decision-Making Unit (DMU) is determined by its ability to transform inputs into aimed outputs. In this sense, the educational efficiency is defined as the ability to produce the maximum amount of educational service. For measuring efficiency, we use a nonparametric deterministic method that allows us to investigate changes in the countries' efficiency standards, namely a model based on the Data Envelopment Analysis (DEA). The DEA model is a nonparametric method of measuring the efficiency of a DMU with multiple inputs and/or multiple outputs. This technique differs from other efficiency analysis, as DEA observes single units and compares them to others, rather than finding averages of all units. DEA model calculates the amount of inefficiency for every unit, according to the best DMU, and puts others on the efficiency frontier or under it. To calculate the efficiency, DEA needs to run n times for each DMU and find the most efficient DMUs, which are then compared to others.

The two most widely used DEA models, are the DEA-CCR model, introduced in [2] and the DEA-BCC model, introduced in [3]. The DEA-CCR model assumes constant returns to scale and the DEA-BCC model, on the other hand, allows for variable returns to scale. DEA is one of the most important approaches to measuring efficiency, with its use for educative performance measurement. In [4] a set of public and private high schools is compared, using DEA. In [5] the efficiency of public and publicly subsidized private high schools is compared. In [6], DEA techniques were applied, to evaluate the comparative efficiency of public higher education institutions. Other interesting studies are [7], [8], [9] and [10].

In this study is used the DEA-CCR, in combination with other mathematical techniques. In addition to calculating the DEA efficiency score for each country, we calculated two important indicators: the group efficiency indicator, which allows giving a recommendation of the variables that could be improved to increase the efficiency, and the accumulated effort indicator which allows measuring the effort of the countries to get input resources in a sequence of years.

The remainder of the paper is laid out as follows. In the next section, a brief overview of the education system in European countries is given. Section 3 presents the data of the study and discusses the DEA approach used in this work. Section 4 presents the main results and, in Section 5, some concluding remarks are formulated.

2. DATA AND METHODOLOGY

2.1 Sources of Data and Definition of Variables

This work examines the quality of education in European countries using a model nonparametric deterministic for measuring efficiency based on DEA (Data envelopment Analysis) [2], in combination with other mathematical techniques. Specifically, we analyzed the (technical) efficiency of 17 European countries: BE (Belgium); CZ (Czechia); DK (Denmark); DE (Germany); IE (Ireland); EL (Greece); FR (France); IT (Italy); LV (Latvia); LU (Luxembourg); HU (Hungary); PL (Poland); PT (Portugal); FI (Finland); SE (Sweden); IS (Iceland) and CH (Switzerland). To this end, were considered seven years (every three years from 2000-2018): 2000, 2003, 2006, 2009, 2012, 2015, 2018.

The study is based on the EU's set of indicators to monitor progress towards the UN SDGs: basic education (early leavers from education and training, participation in early childhood education and achievement in reading, mathematic or science), tertiary education (tertiary education attainment and employment rates of recent graduates) and adult learning (adult participation in learning). The variables were extracted from the Eurostat database for each country and distribuited thus:

Table 1. Variables.

Inputs		Outputs	
VI1	Participation in early childhood education	VO1	Early leavers from education
VI2	Achievement in reading, mathematic or science	VO2	Tertiary education attainment

VI3	Adult participation in learning	VO3	Employment rates of recent graduates

In general terms, efficiency models try to minimize resources (inputs), as production (outputs) increases. However, since a V01 is obviously undesirable in this studyy, the so-called variable complement (CV01) is used instead. Complement variables CV01 is defined as the maximum value of the output variable in an entire database minus the value of the variable for the unit under consideration.

2.2 Methodology

2.2.1 Data Envelopment Analysis

The DEA (Data Envelopment Analysis) technique is a non-parametric technique that allows to calculate the efficiency and that is sustained in a linear programming between all DMU (decision-making units). This technique shows an efficiency frontier, where the relationship between products (outputs) and inputs (inputs) must reach this boundary to be in an optimal "state" of its relationship between the quantity produced and its resources, that is, it has to produce the maximum in relation to its input.

In this study is used the DEA-CCR model introduced by [1]. The DEA-CCR model assumes Constant Returns to Scale (CRS) model for the efficiency measurement of decision-making units, it is the set:

$$\Lambda^n = \{\lambda \in \mathrm{R}^N : \lambda \mathrm{n} \geq 0\}.$$

Thus, all observed production combinations can be scaled up or down proportionally.

Initially, the CCR model was developed with an input orientation model (a variation in the input, will result in a variation in the output, due to the growing returns to scale). In this study, we use the model, output oriented CCR model (see (1)-(2)).

In what follows, we give a general description of the model and fix notation.

Let $k = (c, t) \in \mathrm{N}$ be a tuple identifying the country $c \in C$ and year $t \in T$, which we call a country/year tuple, and $[m]$ denotes the set $\{1, \ldots, m\}$, for some $m \in \mathrm{N}$. We consider that any given tuple $n \in \mathrm{N}$ produces $J \in \mathrm{N}$ outputs $y_j(n)$, $j \in [J]$, using $I \in \mathrm{N}$ inputs $x_i(n)$, $i \in [I]$. The efficiency relative of a DMU k can be obtained by solving the following program:

$$\min h_k \sum_{i=1}^{n} v_i x_{ik} \tag{1}$$

Subject to

$$\sum_{r=1}^{m} u_r y_{rj} - \sum_{i=1}^{n} v_i x_{ij} \leq 0 \tag{2}$$

$$\sum_{r=1}^{m} u_r y_{rk} = 1 \tag{3}$$

$$u_r, v_i \geq 0$$

where h_k = efficiency of DMU k, which will be analyzed, u = weights of the outputs; v= weights of inputs; r = 1,…,m; i = 1,…,n and j = 1,…,N.

Definition 1: For a given dataset $Z=\{z(k)\}_N$ with z(k)=(x(k),y(k)), the DEA efficiency score of each DMU k∈ N, is then defined as the value h_k, $0 \leq h_k \leq 1$, such that h_k satisfies (1)-(2).

The data processing is done supported by a software package developed in Python for conducting data envelopment analysis, called pyDEA. The documentation can be found at https://araith.github.io/pyDEA/.

2.2.1 Group indicator

To study the differences that can be found between groups with different levels of efficiency (groups more and less efficient), we defined the group efficiency indicator. It allows giving a recommendation of the variables that could be improved (in groups with less efficient) to increase the efficiency.

According to the DEA efficiency score two different groups were considered: the group G_1 corresponding to the most efficient countries and the group G_0 corresponding to the less efficient countries, and we defined the following indicator.

Definition 2: The group efficiency indicator $\mathrm{EG}_{G1.G0}(x_i(n))$ for an input $x_i(n)$, is given by:

$$E\mathrm{G}_{\mathrm{G1.}G0}(x_i(n)) = \frac{m_{G1}(x_i(n)) - m_{G0}(x_i(n))}{m_{G0}(x_i(n))} \quad (4)$$

where $m_{G1}(x_i(n))$ is the mean of the input $x_i(n)$, for the efficient group G_1 and $m_{G0}(V_i)$ is the mean of $x_i(n)$ for the less efficient group G_0.

The group efficiency indicator represents the relative value of the difference between the groups G_1 and G_0 for each input. Following the same idea of the definition 2 and equation (4), the indicator $\mathrm{EG}_{G1.G0}(y_j(n))$ can also be defined for each output $y_j(n), j \in [J]$.

2.2.2 *Effort Indicator*

An indicator to measure the effort of the countries to obtain input resources in a sequence of years, is defined to continue.

Definition 3: Let V be the set of units with DEA efficiency score> 0.9. The effort indicator of the set V of units between the period t_{j-1} and the period t_j, is defined by:

$$\mathrm{EI}_{t_{j-1}t_j}(\mathrm{V}) = -1 + \frac{1}{\bar{\mathrm{I}}} \sum_{i\in[\bar{I}]} \frac{\min\{x_i(c,t_j):c \in V\}}{\min\{x_i(c,t_{j-1}):c \in V\}}, \quad (5)$$

where $\bar{\mathrm{I}}$ is the subset of input indices for which both minima are different from zero in the periods t_{j-1} and t_j.

The total effort made by each country in each year is determine by the accumulated effort indicator.

Definition 4: Let V be the set of units with DEA efficiency score> 0.9. The accumulated effort indicator of the set V of units, is calculated by:

$$\mathrm{AEI}_{t_l}(V) = \sum_{l\in\{1,\ldots,m\}} \mathrm{EI}_{t_{j-1}t_j}(V). \quad (6)$$

where EI is defined as (5).

3 EMPIRICAL RESULTS AND ANALYSIS

We analyze the evolution countries with respect to SDGs at three efficiency stages: levels, patterns, and determinants. The analysis performed consists in following main steps:

• General analysis using DEA efficiency score (A1).

• Analysis of groups with different levels of efficiency (A2).

• Analysis of the accumulated effort (A3).

3.1 General analysis using DEA efficiency score (A1).

DEA score (Equation xxx) was calculated for all countries of the study. We present the scores got in Table 2, establishing a ranking of countries by year.

Table 2. Ranking countries by year.

2006		2009		2012		2015		2018	
EL	1	CH	1	CH	1	CH	1	CH	1
HU	1	HU	1	CZ	1	CZ	1	CZ	1
IE	1	IE	1	DE	1	DE	1	EL	1
FI	1	FI	1	EL	1	EL	1	FI	1
PL	1	PL	1	FI	1	FI	1	HU	1
PT	0,99542	EL	0,991376	HU	1	IE	1	IE	1
FR	0,919255	FR	0,975525	IE	1	PL	1	PL	1
CH	0,919037	BE	0,914005	PL	1	LU	0,96716	DE	0,99949
BE	0,857576	PT	0,880395	LU	0,964271	LV	0,944365	LU	0,961191
CZ	0,849217	DK	0,854349	BE	0,94218	IS	0,936948	LV	0,958269
LU	0,809067	DE	0,847173	FR	0,913442	SE	0,932766	BE	0,937189
DK	0,797548	CZ	0,843174	LV	0,890555	HU	0,929543	SE	0,937023
DE	0,785253	LU	0,834962	SE	0,854753	BE	0,917735	IS	0,932238
IS	0,768482	IS	0,806663	IS	0,848643	DK	0,885095	DK	0,919333
SE	0,768341	SE	0,800391	DK	0,799396	PT	0,83787	PT	0,883616
LV	0,75188	LV	0,770695	PT	0,760199	FR	0,798239	FR	0,792689
IT	0,638142	IT	0,577923	IT	0,610437	IT	0,567951	IT	0,637747

Color	Scores description	Countries number
	0,5< score DEA≤0,6	2
	0,6< score DEA≤0,7	3
	0,7< score DEA≤0,8	10
	0,8< score DEA≤0,9	16
	0,9< score DEA≤1	54

In general terms the countries studied are efficient, the 82,3% of the sample had a high efficiency (0,8≤DEA score≤1). As we can see in Table 3, the countries IE, FI and PL had efficiency maximum (DEA score=1) in all study period. On the other hand, IT is the country with the lowest efficiency score (0,577923≤DEA score≤0,638142) during the study. For a better visualization, in the Figure 1 the behavior of the DEA score of the countries in each year is represented.

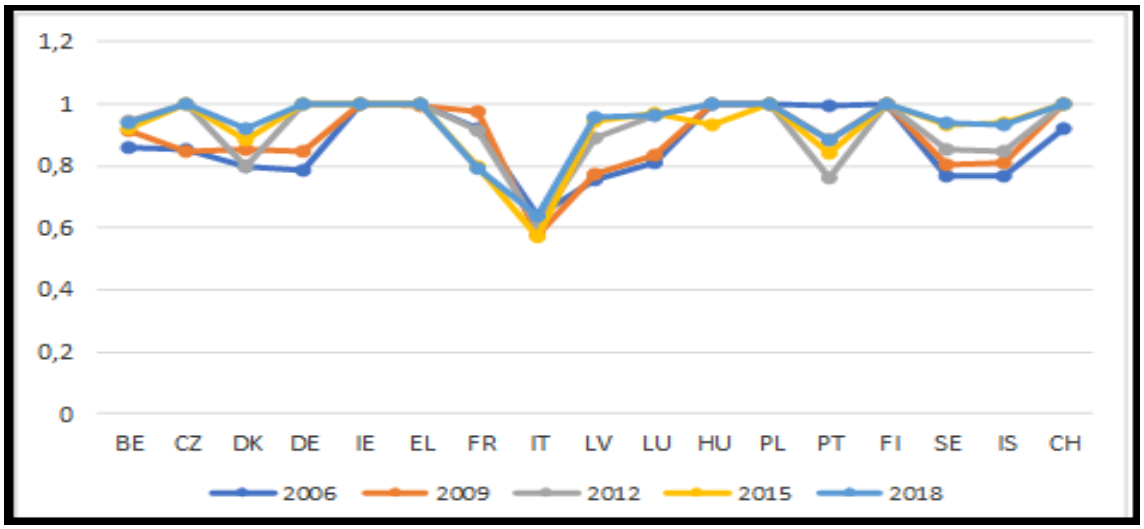


Figure 1. DEA scores.

3.2 Analysis of groups with different levels of efficiency (A2)

Although there is a large percentage of efficient countries (94,1%), it is important to bear in mind that the level of efficiency is not the same in all countries and in all years. According to the results obtained in 3.1, we define six efficiency levels: Null-EFF (countries with null efficiency); Not-EFF (countries not efficient); Low-EFF (countries with low efficiency); Medium-EFF (countries with medium efficiency); High-EFF (countries with high efficiency) and Full-EFF (countries with Maximum efficiency, see the corresponding description in Table 3.

Table 3. Efficiency level.

	Efficiency level	Description	Country's Number	Percentage (%)
Inefficiency	Null-EFF	score DEA=0	0	0
	Not-EFF	0 < score DEA<0,7	5	5,8
Efficiency	Low-EFF	0,7 ≤ score DEA<0,8	10	11,7
	Medium-EFF	0,8 ≤ score DEA<0,9	16	18,8
	High-EFF	0,9 ≤ score DEA<1	22	25,8
	Full-EFF	score DEA=1	32	37,6

Figure 2 shows how the efficiency level (in percentages) evolve with time. We find a considerable percentage of efficient countries per year. Specifically, in High-EFF and Full-EFF levels in the last two years.

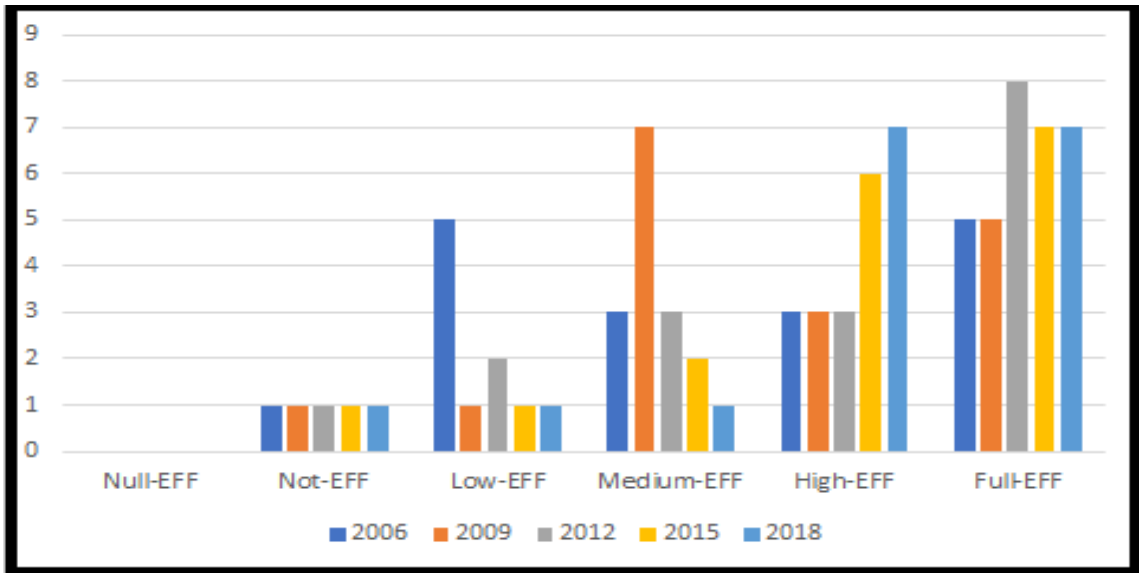
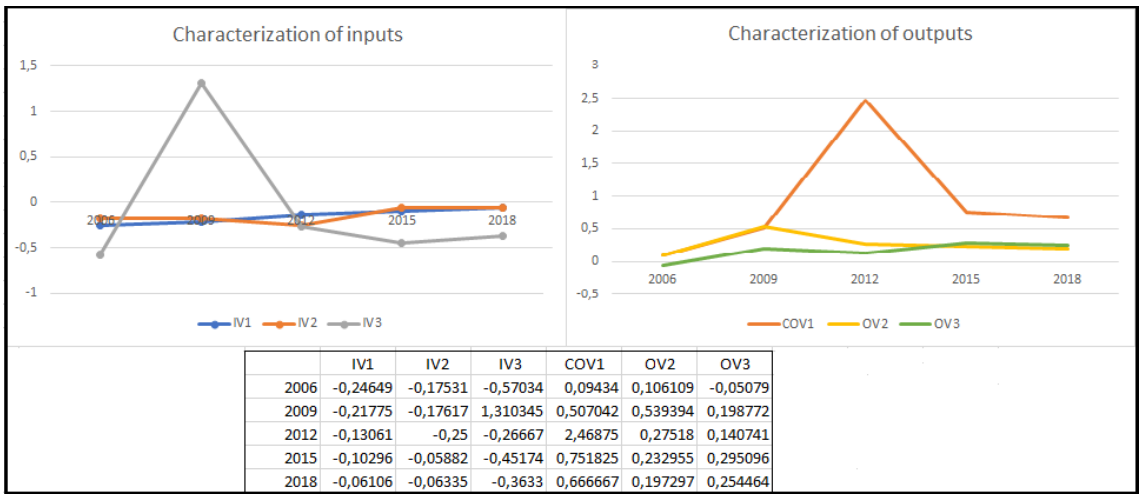


Figure 2. Null-EFF, Not-EFF, Low-EFF, Medium-EFF, High-EFF and Full-EFF yearly evolution.

In order, to the calculate the group efficiency indicator (Figure 3), two groups with different DEA efficiency scores were considered: the group G1 corresponding to the most efficient countries (countries with Full-EFF), and the group G0 corresponding to the inefficient (countries Not-EFF) and the less efficient countries (countries with Low-EFF). In 2006, G1 group is formed by the countries EL, HU, IE, FI, PL. Go group by the countries DK, DE, IS, SE, LV, and IT. In 2009, G1 group is formed by the CH, HU, IE, FI and PL. Go group by the countries LV and IT. In 2012 G1 group is formed by the countries CH, CZ, DE, EL, FI, HU, IE and PL. Go group by the countries DK, PT, and IT. In 2015 G1 group is formed by the CH, CZ, DE, EL, FI, IE and PL. Go group by the countries FR and IT. In 2018 G1 group is formed by the CH, CZ, EL, FI, HU, IE and PL. Go group by the countries FR and IT.



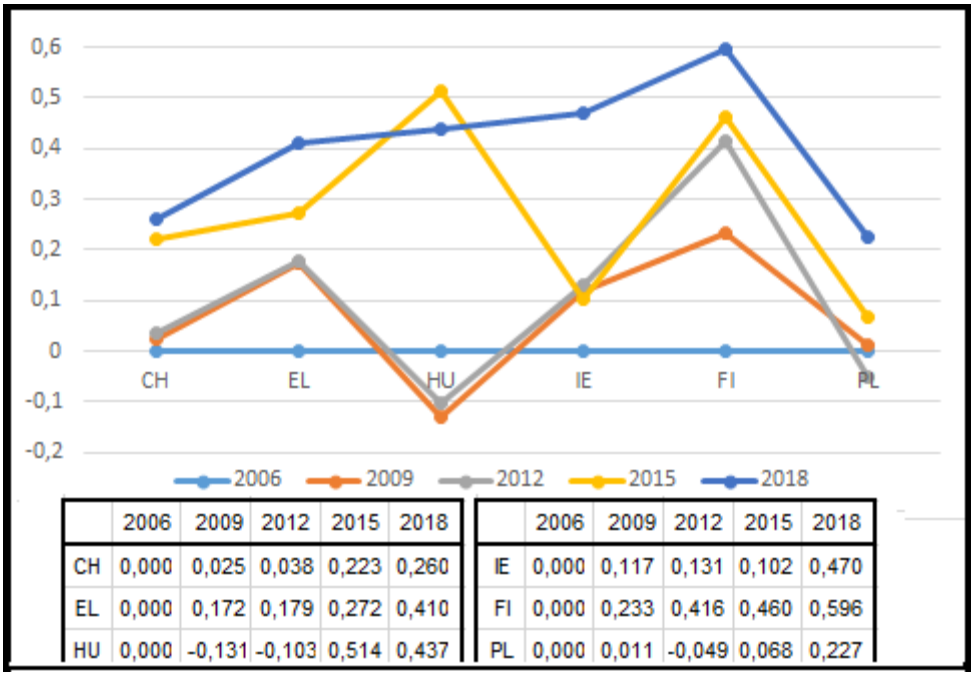
	IV1	IV2	IV3	COV1	OV2	OV3
2006	-0,24649	-0,17531	-0,57034	0,09434	0,106109	-0,05079
2009	-0,21775	-0,17617	1,310345	0,507042	0,539394	0,198772
2012	-0,13061	-0,25	-0,26667	2,46875	0,27518	0,140741
2015	-0,10296	-0,05882	-0,45174	0,751825	0,232955	0,295096
2018	-0,06106	-0,06335	-0,3633	0,666667	0,197297	0,254464

Figure 3. Characterization of inputs, efficient versus non-efficient groups.

The Group Efficiency indicator allows giving a recommendation of the variables that could be improved to increase the efficiency. Note that the input that presents less difference in absolute value between the two groups is the variable IV2 (2015) with 0,05, and the input with the highest index (both in natural and absolute value) is the variable IV3 (2009) with 1,31. In the output case, the less difference in absolute value is found in the variable 0V3 (2006) with 0,05, and the output with the highest index (in absolute value) is the variable COV1 (2012) with 2,46.

3.3 Analysis of the accumulated effort (A3)

In order, to calculate the accumulated effort, we selected the countries with DEA score> 0.9 in all years of study: CH, EL, HU, IE, FI and PL.



	2006	2009	2012	2015	2018
CH	0,000	0,025	0,038	0,223	0,260
EL	0,000	0,172	0,179	0,272	0,410
HU	0,000	-0,131	-0,103	0,514	0,437

	2006	2009	2012	2015	2018
IE	0,000	0,117	0,131	0,102	0,470
FI	0,000	0,233	0,416	0,460	0,596
PL	0,000	0,011	-0,049	0,068	0,227

Figure 4. Accumulated effort.

In Figure 4 are presented the results for each these countries in each year to reach the inputs required to reach the ideal performance (i.e., the one that is able to minimize all the inputs and, at the same time, maximize all the outputs). As we can see, in 2018 nearly all countries (except HU) had a higher effort.

4 CONCLUSIONS

This paper analyses the progress made towards Goal 4 in the implementation of the 2030 Agenda (2015-2018) proposed by the UN for Sustainable Development. The analysis is done using CCR-DEA model with other mathematical techniques and following an output-oriented model in a structure every three years between 2006 and 2018.

The most important findings in this article are as follows: (1) The performance of the indicators evaluated improved markedly in 2018, reflecting that all countries in the study are working hard to achieve Goal 4, proposed by the UN. Note that the agenda was adopted by the 193 countries in September 2015. It was to be expected that most of them (if not all) started from that time on, applying a set of strategies that would improve their performance. (2) Although there is a large percentage of efficient countries (94.11% in all sample), it is important to keep in mind that the level of efficiency is not the same in all countries and every year. According to the results, we found different levels of efficiency (the percentages shown in brackets involve all the years) Null-EFF (0%), Not-EFF (5.8%), Low-EFF (11.7%), Medium-EFF (18.8%), High-EFF (25.8%) and Full-EFF (37.6%). (3) The Group Efficiency indicator allows you to recommend the variables that can be improved to increase efficiency. The biggest difference between the efficient and non-efficient groups is the input variable IV3 (2009) with 1.31 and the output variable COV1 (2012) with 2.46. The most efficient countries have a greater participation of adults in learning and less early school leaving. Least efficient countries should work on improving these indicators. (4) The only inefficient country throughout the study period was IT with a DEA score below 0.64 (2006, 2012 and 2018) and below 0.58 (in 2009 and 2015). In Italy, ASviS – Italian alliance for sustainable development is the promoter of the Agenda 2030 with the aim of enhancing the awareness of the importance of the programme in Italian society. Although some strategies are already being

applied, Italy is still under debate in terms of efficiency, from many countries of the European Union. It needs to be reorganized for a prompt and effective improvement. Contrary to this, the most efficient countries were CH, EL, HU, IE, FI and PL, maintaining a score above 0.9. On the other hand, in general terms to get a high level of efficiency, four of these countries presented a cumulative effort higher in 2018 (CH, EL, IE, FI and PL). HU presented a greater effort in 2015.We underline that the Sustainable Development Goals (SDGs) are quite ambitious and reaching the proposed goals until 2030 will not be an easy task. It must be recognized that the challenges may be greater for some countries than for others, due to their social, economic, and even geographical conditions. Although many of them are beginning to show considerable progress, the rate of progress observed is delayed and ends up being insufficient to fully meet each of the SDGs and the 2030 targets. However, the initiative and the commitment made are highly applauded 193 countries, to seek a more equitable and quality world. A periodic review of the assumed strategies is important, in order**,** to correct aspects that limit or intended scope.

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