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Sustainable Development and Workers Ability: Considerations on the Education Index in the Human Development Index

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Abstract: Sustainability is an imperative of the 21st century in order to preserve the environment for the next generations, but sustainable development also requires the introduction and use of new technologies, and the related abilities for their use. The United Nations have adopted the Human Development Index HDI in order to assess human well-being. This index includes a component related to knowledge, the Education Index, which is expressed in terms of the mean schooling years. However, this information does not contain a measure of the student's ability to solve complex problems or ability to reason, which are fundamental skills for sustainable development. In this study, an improved version of the Education Index was developed by considering the data available from the OECD's Programme for International Student Assessment (PISA). This new index takes into account both the social impact of schooling years and the outcomes of the education systems for each country (PISA scores). As a consequence of this new Education Index, a new Human Development Index, HDI^*, is proposed. Two case studies were performed, comparing the European and non-European countries, focusing on government education spending. Moreover, the trends of an energy and an environmental indicator are analyzed in relation to the HDI^*.

Keywords: sustainability; indicators; energy indicators; Education Index; OECD-PISA indicator; human well-being

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1. Introduction

In the 1970s, the concept of sustainability was initially introduced [1,2], meaning preserving environmental conditions [3,4] in relation to a continuous technological development of societies [5]. In 1980, the concept of sustainable development was consequently introduced [6–9], and a dynamic model was developed in order to evaluate the interactions between humans and Earth, in relation to food production, industrialization, non-renewable resources, pollution, and population [10–12]. Thus, the need for integrating conservation with development emerged, and a related change in viewpoint emerged in order to use the Earth's limited resources in a more sustainable way. Indeed, a global approach was highlighted for resource management, addressing the following issues:

- The conservation of global ecosystems;
- The interconnection between local and global actions.

Sustainable development [13] suggests development "that meets the needs of the present without compromising the ability of future generations to meet their own needs" [14]. This statement points out the need to integrate economic growth with social (equity based) and environmental issues [15,16].

At present, sustainable development [17,18] is increasingly moving towards human well-being for present and future generations [19]. It requires:

- Monitoring the performance of a country: this is possible only by introducing effective indexes of sustainability;

- Determining priorities and choices for governments, based on the quantitative results obtained by some effective indexes of sustainability.

However, the issue is to identify the quantitative and qualitative measures [20] for the sustainable development, in order to collect the useful information on the well-being of a country [21,22]. With this aim, in 2000, the *United Nations Millennium Development Goals* (MDGs) were introduced, in order to achieve social priorities worldwide [23]. They pay special regard to energy, health, poverty, gender inequality, schooling, and environmental degradation. In 2015, improvements in the MDGs were developed [24] for the UN plan for action, called the *2030 Agenda for Sustainable Development*. In this context, a new viewpoint emerged [25], in order to highlight the lever effect of the economic activities for the Sustainable Development Goals (SDGs) results, but also to highlight the related difficulties in achieving the new goals in these main areas: people, planet, prosperity, peace, and partnership.

In this context, the Human Development Index (HDI) was introduced [26,27]. Since 1990, the United Nations Development Programme (UNDP) has used HDI as a multidimensional index to measure the development of a country based on a socio-economic viewpoint, particularly focused on human well-being. This index was introduced as a complementary measure to the mono-dimensional Gross Domestic Product (GDP), in order to consider both social and economic aspects, for the evaluation of the development of a country, highlighting the role of people's well-being and quality of life [28–30]. Thus, the aim of this index is to evaluate a country from a human-centered viewpoint and not only from a purely economic one [27,31,32]. In the first Human Development Report (HDR), human development was defined as *the process that enlarges people's choices* [26]. These are infinite, and can vary over time. However, three aspects were identified as essential and indispensable: living a long and healthy life, acquiring knowledge, and having access to resources for a decent standard of living. These three aspects are taken into account by using, respectively, the following three social and economic indicators: life expectancy from birth, schooling years, and gross national income per capita [31,33–36].

As previously highlighted, within the HDI, there is an index related to education that represents school enrollment rate , which represents prevention of child exploitation, but it does not represent a measure of the children's ability to solve complex problems or reason, which is one of the key requirements for the productivity of the future work force as a whole. Indeed, the new approach to work requires the ability to adapt to changes, and the ability to conceptualize complex ideas in a multidisciplinary setting [37–42]. In the context of sustainable development, these abilities are crucial to facing actual global challenges and sustainability issues, and dealing with the resulting choices from a multidisciplinary viewpoint, since sustainable societies require the development of new solutions and technologies, in order to reduce their environmental anthropic footprints, and to ensure well-being for all people. In order to do so, scientific knowledge and problem solving abilities are essential. Consequently, the HDI index must be analyzed in relation to education, in order to improve it by introducing a measure of the abilities of students, for the optimization of the educational approaches in relation to the demands of modern work.

In this paper, we analyze the HDI indicator, with the aim of improving it by considering the OECD's Programme for International Student Assessment (PISA) results. Indeed, since 2000, PISA has been a worldwide study by the Organization for Economic Co-operation and Development (OECD) in member and non-member nations. Its aim is to evaluate educational systems by measuring 15-year-old school pupils' scholastic performances in Mathematics, Science, and Reading. The results of the PISA analysis provide comparable data for the improvement of education policies and outcomes in the analyzed countries.

2. Materials and Methods

In this section, the United Nations' Human Development Index (HDI) is analyzed, with a particular focus on its educational component: The aim is to improve the Education Index by introducing a term related to students' outcomes.

HDI considers three fundamental aspects of sustainable development: (i) a long and healthy life, (ii) access to education and (iii) a decent standard of life [43]. Each of these aspects is represented by a normalized index, which are merged into a single index (HDI), by using their geometric mean. Thus, the Human Development Index (HDI) [44] is defined as follows:

$$HDI = \left(LEI \cdot II \cdot EI_{UN} \right)^{1/3} \quad (1)$$

where:

- LEI is the normalized Life Expectancy Index, defined as follows [33]:

$$LEI = \frac{LE_{actual} - LE_{min}}{LE_{max} - LE_{min}} \quad (2)$$

  where LE is the life expectancy at birth [yr], and the subscripts $actual$, max and min are, respectively, the value of life expectancy at birth in the considered year, its maximum and minimum values adopted for the normalization by the United Nations;
- II is the normalized Income Index, which is evaluated by considering the Gross National Income per capita GNI_{pc} at purchasing power parities (PPP) [$\$_{pc}$ PPP] [33]:

$$II = \frac{\ln\left(\frac{GNI_{pc,actual}}{GNI_{pc,min}}\right)}{\ln\left(\frac{GNI_{pc,max}}{GNI_{pc,min}}\right)} \quad (3)$$

  The GNI_{pc} is defined as "the sum of value added by all resident producers in the economy plus any product taxes (excluding subsidies), not included in the valuation of output plus net receipts of primary income (compensation of employees and property income) from abroad, divided by midyear population. Value added is the net output of an industry after adding up all outputs and subtracting intermediate inputs" [33]. Considering the purchasing power parity (PPP) allows us to highlight the different conditions in purchasing power among countries by deleting differences in the price level [35]. A logarithmic normalization is adopted for the Income Index, in order to consider that higher incomes have a declining contribution to human development [44].
- EI_{UN} is the normalized Education Index, which considers two different information, related both to the mean years of schooling and to the expected years of schooling. It is defined as the arithmetic mean value of the related indexes, as follows:

$$EI_{UN} = \frac{I_{MYS} + I_{EYS}}{2} \quad (4)$$

  where
  - I_{MYS} is the Mean Years of Schooling index, defined as:

$$I_{MYS} = \frac{MYS_{actual} - MYS_{min}}{MYS_{max} - MYS_{min}} \quad (5)$$

    where MYS is the Mean Years of Schooling, which is the average number of completed years of education, attended by the country's population aged 25 years and older;

– I_{EYS} is the Expected Years of Schooling Index, defined as:

$$I_{EYS} = \frac{EYS_{actual} - EYS_{min}}{EYS_{max} - EYS_{min}} \quad (6)$$

where EYS is the Expected Years of Schooling, which is the number of years a child of school entrance age is expected to spend at school, or university (sum of the age-specific enrollment ratios for primary, secondary, post-secondary non-tertiary and tertiary education).

In order to calculate the normalized values of the previous indexes, their minimum and maximum values are needed. In this paper, we use the values adopted by the United Nations and summarized in Table 1.

Table 1. Values adopted by the UN [44] to normalize the indexes in Equations (2)–(6), in order to obtain the HDI.

Indicator	Unit	Minimum Value	Maximum Value
LE	yr	20	85
$GNI_{pc,PPP}$	$\$_{pc}$ 2017 PPP	100	75,000
MYS	yr	0	15
EYS	yr	0	18

Education Index, EI_{UN}, considers the country's educational attainment, by introducing the average adult years of schooling and the expected years of schooling for students. These are fundamental aspects from a social viewpoint, representative of a better quality of life [45], but also in avoiding child labor. However, this index is not able to provide information on the student's individual skills related to problem-solving abilities and technical/scientific knowledge; indeed, these skills represent key levers for technology improvements, but also the bases for more sustainable global conditions. Consequently, all these aspects must be introduced in the Education Index, in order to perform the assessment of a country's education level, and its sustainable potential. Thus, here, in order to account these considerations, we propose to include the results of the OECD's Programme for International Student Assessment (PISA) into the Education Index.

In this context, we must highlight that the PISA project is an international large-scale assessment (ILSA) on students educational achievements, with items that are meant to address real life challenges. This assessment is owned and governed by member states in the OECD, and it is considered one of the most influential studies in global education [46,47]. Thus, the OECD's Programme for International Student Assessment (PISA) has been developed by the Organization for Economic Co-operation and Development to track the outcomes of educational systems, as regards student's achievements. In particular, its aim is to measure 15-year-old school pupils' scholastic performance on Mathematics, Science, and Reading [48]. The OECD's Programme for International Student Assessment is a triennial assessment, which provides information on some core school subjects, focusing on the students' abilities built from the knowledge acquired during their schooling pathway [48].

In order to obtain a normalized indicator from the OECD's PISA results, the following relations can be used for each discipline envisaged on this assessment (Reading, Mathematics and Sciences):

- Reading:

$$I_{Rdn} = \frac{Rdn_{actual} - Rdn_{min}}{Rdn_{max} - Rdn_{min}} \quad (7)$$

where I_{Rdn} is the normalized indicator for the OECD's PISA results in Reading (Rdn) for a country, Rdn_{actual} is the Reading score of the country, in the considered year, and the subscripts min and max are referred to the minimum and maximum values, respectively;

- Mathematics:

$$I_{Mth} = \frac{Mth_{actual} - Mth_{min}}{Mth_{max} - Mth_{min}} \tag{8}$$

where I_{Mth} is the normalized indicator for the OECD's PISA results in Math (Mth) for a country, Mth_{actual} is the Math score of the country, in the considered year, and the subscripts min and max are referred to the minimum and maximum values, respectively;

- Sciences:

$$I_{Sci} = \frac{Sci_{actual} - Sci_{min}}{Sci_{max} - Sci_{min}} \tag{9}$$

where I_{Sci} is the normalized indicator for the OECD's PISA results in Sciences (Sci) for a country, Sci_{actual} is the Sciences score of the country, in the considered year, and the subscripts min and max are referred to the minimum and maximum values, respectively.

The aim of this paper is to suggest an improvement of the actual Education Index, by introducing the PISA-OECD results. To do so, the maximum and minimum values of the previous PISA indicators must be defined, considering that the values of the PISA indicators are time dependent; indeed, their maximum and minimum values are different in different years. Moreover, the different annual results must be compared one another. Thus, the maximum value is the absolute maximum in the time range considered. Consequently, the indicators must be re-evaluated every time as the PISA tests are updated. However, it is the easy way to obtain the evaluation of these indicators. In the same way, we evaluate the minimum. Thus, for each discipline, the numerical minimum and maximum values have been evaluated by considering all the data available up to now. Their values are reported in Table 2. Last available data are referred to 2018.

Table 2. Maximum and minimum values adopted for the normalization of Equations (7)–(9) related to OCSE PISA results. Data of OECD-PISA assessment are available in Refs. [49,50].

Indicator	Minimum Value	Maximum Value
Rdn	312	556
Mth	318	591
Sci	332	590

In order to group all the information of the OECD PISA assessment, we use the average value of the normalized scores of the three domains, obtaining the following Education Index:

$$EI_{OP} = \frac{I_{Rdn} + I_{Mth} + I_{Sci}}{3} \tag{10}$$

where EI_{OP} is the Education Index, related to the OECD PISA normalized scores, defined by the previous Equations (7)–(9).

Therefore, in order to take into account both the social impact of schooling years (already considered by the EI_{UN}), and the outcomes of education systems in terms of technical skills, a broader Education Index (EI^*) is here proposed:

$$EI^* = \frac{EI_{UN} + EI_{OP}}{2} \tag{11}$$

In this way, the fundamental social features of schooling years are considered, including also the aspects of student's skills, which represent their training tool to face the actual and future challenges.

Thus, introducing this new Education Index (EI^*) into the HDI, we can obtain the improvement of the Human Development Index, HDI^*, that, now, results are also professional oriented, because of the new component related to pupil's technical competences:

$$HDI^* = \left(LEI \cdot II \cdot EI^*\right)^{1/3} \tag{12}$$

Lastly, we will analyze two fundamental indicators in the context of sustainable development, related, respectively, to energy (Total Primary Energy Supply), and to the environment (greenhouse gases emissions) [51], in relation to HDI^*. Indeed, the Total Primary Energy Supply is the amount of primary energy, needed to generate the supply of energy carriers, used by the considered society. It has a key role for the development of the society itself. Moreover, the size of the population must be considered in relation to the primary energy disposal of a country. Therefore, the Total Primary Energy Supply per capita ($TPES_{pc}$) will be considered, too. As far as the environmental indicator, the greenhouse gas emissions correspond to the carbon dioxide equivalent emitted into the atmosphere by anthropic activities. Additionally, this quantity will be considered per inhabitant (GHG_{pc}) [52].

3. Results

In this section, two different case studies are proposed. They are referred to in the comparison of two different groups of countries:

- The comparison of the indicators evaluated for the European Union countries;
- The comparison of the indicators between the whole European Union and the other countries.

3.1. Case Study A: Comparison among European Union Countries

This case study concerns all the countries of the European Union. The data are referred to 2018, being the year of more recent available PISA data. These countries have been arranged into four groups, based on the education spending in the country. The estimation of countries' spending is based on the percentage of the Gross Domestic Product (GDP) allocated for primary and lower secondary education. Moreover, in order to weight this spending in relation to the country size, we have considered the amount of the GDP allocated for primary and lower secondary education per student [53–55]. The classification range considered for the EU countries is shown in Table 3. In Figure 1, the related countries are shown in relation to the classification scheme of Table 3. In order to consider the time fluctuations of each country's spending, its average value has been adopted, and calculated by considering the spending of the seven years, before the last available PISA survey (by now, 2018). The average for each country are summarized in Figure 1.

Table 3. Case Study A. Group subdivision of the European Union countries, based on their expenditures on education.

Group Name	Range [\$ yr^{-1} student^{-1}]
EU1	>12,000
EU2	9000–12,000
EU3	6000–9000
EU4	<6000

The first analysis proposed (Figure 2) concerns the United Nations Education Index (EI_{UN}), and its two components, the Mean Years of Schooling (I_{MYS}) and the Expected Years of Schooling (I_{EYS}). For I_{MYS}, a higher education spending cannot be uniquely related to a high number of school years. In particular, in relation to the I_{MYS} average values, it is possible to highlight that:

- EU1 with EU2 present the same value, despite EU1 education spending is higher than EU2 one;
- EU3 has a lower I_{MYS} value than EU4, despite EU3 education spending is higher than EU4 one.

Moreover, an increase in the education spending causes an increase in the EI_{UN} index.

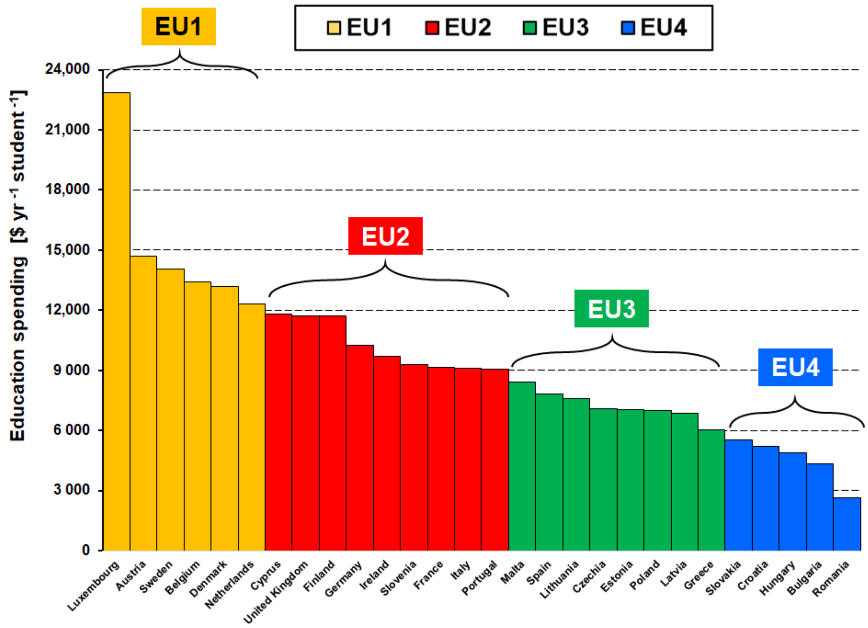

Figure 1. Case Study A. European Union countries divided by government spending on education per student, referred to the percentage of GDP for primary and lower secondary education; raw data are available in Refs [53–55].

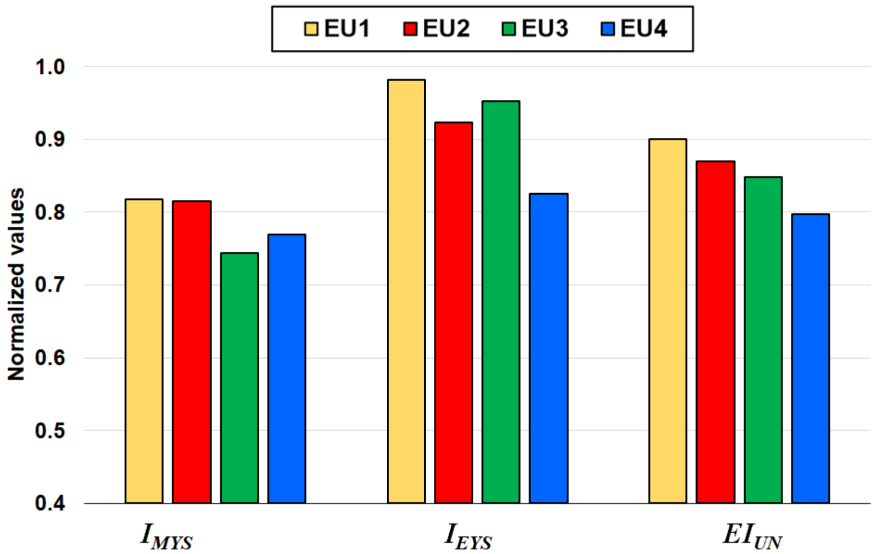

Figure 2. Case Study A. United Nations Education Index, EI_{UN}, and its components: I_{MYS} (normalized Mean Years of Schooling), I_{EYS} (normalized Expected Years of Schooling). This data are referred to the last year available for the OECD PISA assessment (2018). Raw data of the UNs indicators are available in Refs [56–58].

The second analysis proposed (Figure 3) concerns the OECD PISA results. Considering the I_{Rdn} values for EU1, EU2 and EU3, it is possible to point out that there are no significant correlations with the education spending, while, in relation to I_{Mth} and I_{Sci}, their values decrease with the reduction of education spending. In all the cases considered, the EU4 (i.e., countries with an educational expenditure lower than 6000 \$ student^{-1}) presents lower values, if compared to the other groups. The Education Index based on the pupil's skills ascertained by the OECD PISA, EI_{OP}, merges all the scores on the three domains assessed. A significant increase in this index (+0.18) can be observed between EU4 and EU3, while the increase results are smaller (+0.02) in EU3, EU2 and EU1. Considering the values of

EU4, in Figure 3, a spending threshold can be pointed out; indeed, below this value, the PISA scores reduce sharply; however, very high values of spending do not necessarily make a significant increase in PISA results.

For the four European group, the whole Education Index (EI^*) has been calculated with Equation (11). Consequently, the new Human Development Index (HDI^*) has been obtained from Equation (12). In Figure 4, the time trends of both classical HDI and the modified, HDI^*, indexes are shown. The years considered are the same of the PISA tests administration: 2006, 2009, 2012, 2015 and 2018.

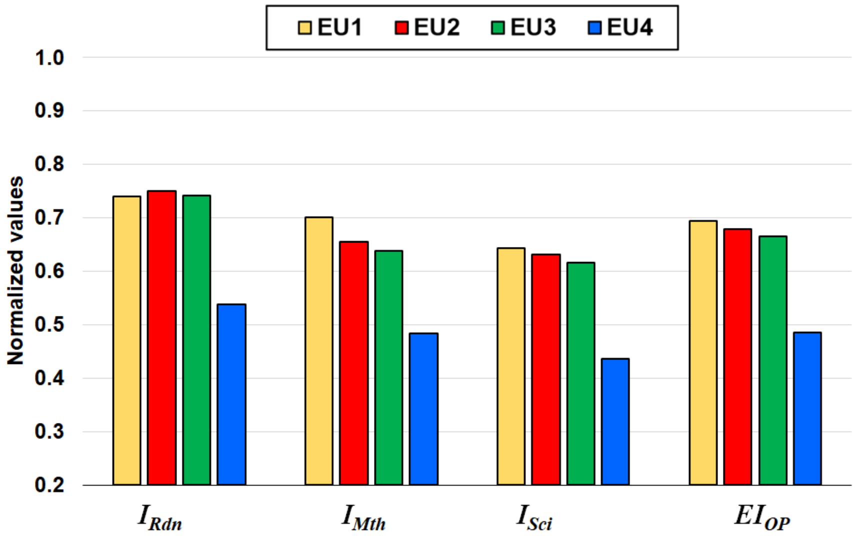

Figure 3. Case Study A. OECD PISA Indexes: I_{Rdn} is the normalized score in Reading, calculated by using Equation (7), I_{Mth} is the normalized score in Mathematics, calculated by using Equation (8), I_{Sci} is the normalized score in Sciences, calculated by using Equation (9), and EI_{OP} is the OECD PISA Education Index, calculated by using Equation (10). Data are referred to the last year available for the OECD PISA assessment (2018), raw data of OECD PISA scores are available in Refs [49,50].

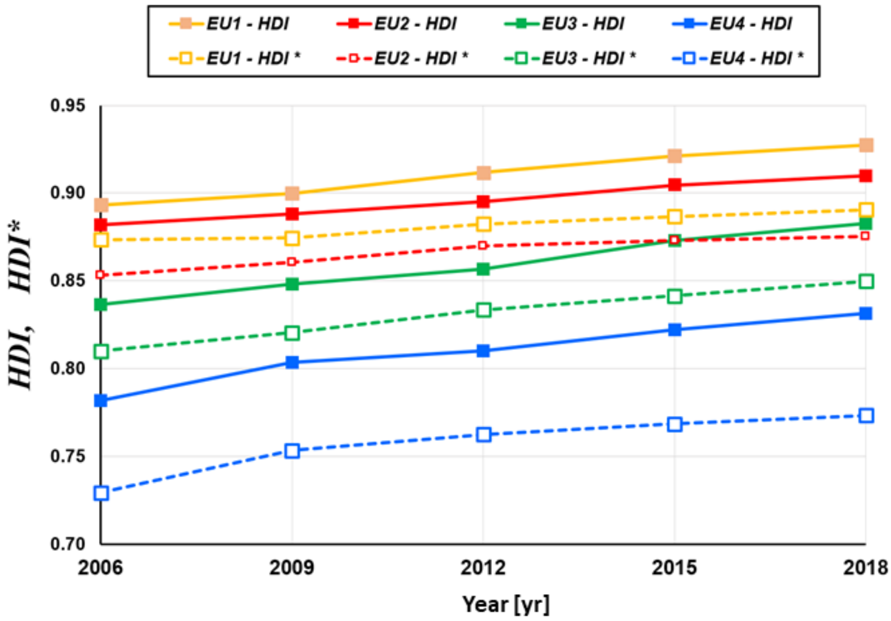

Figure 4. Case Study A. Comparison among European Union countries: HDI and HDI^* results (calculated by using Equation (12)). HDI data are available in Ref. [59], while indicators of Equation (12) are available in Refs [58–61]. All the years in which the PISA tests were carried out are reported (2006, 2009, 2012, 2015, 2018).

Firstly, it can be observed that HDI^* always presents smaller values than HDI. This is due to the new Education Index, EI^*, that assumes smaller values than the United Nations Index, EI_{UN}; indeed, it considers only the schooling years, without any information on the student's skills. This can be highlighted by comparing the results shown in Figures 2 and 3. Moreover, all the trends are increasing over time. This is determined by the II and LEI indexes; indeed, the economic aspect directly affects the Income Index, but it improves the quality of life and, consequently, the life expectancy (Equation (12)).

In Figure 5, the energy indicator Total Primary Energy Supply per capita ($TPES_{pc}$) [62], and the environmental indicator related to Greenhouse Gases emissions per capita (GHG_{pc}) [63] are analyzed in relation to the HDI^*, for the time range considered in OECD-PISA data. In general, for a given HDI value (that is a measure of the development of a country and of its people well-being), the better condition consists in lower values of $TPES_{pc}$ and GHG_{pc} (which are, respectively, a measure of energy needs and of environmental impact). In the upper part of Figure 5, the $TPES_{pc}$ is represented in relation to HDI^*: countries with higher education spending present a high $TPES_{pc}$, due to the link between the education spending and the GDP; indeed, high GDP allows high energy supply for economic activities. Similar trends can be highlighted for $TPES_{pc}$ and GHG_{pc}, because the energy supplies are strongly correlated with the CO_2 emissions.

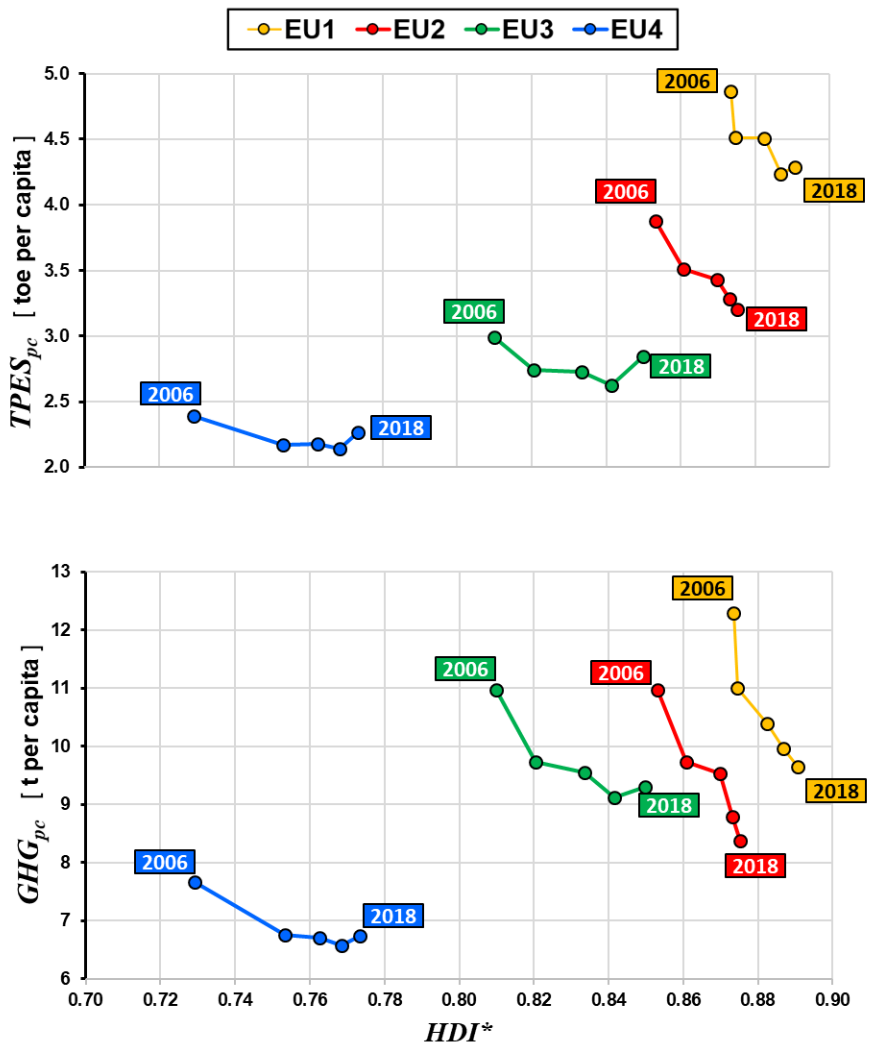

Figure 5. Case Study A. Comparison among European Union countries: $TPES_{pc}$ and GHG_{pc} versus HDI^*. All the years in which the PISA tests were carried out are reported (2006, 2009, 2012, 2015, 2018). Data of GHG_{pc} and $TPES_{pc}$ are available in Refs. [62–64].

Now, we focus on the behavior of the four EU groups. In all of them, the HDI^* has increased on time:

- EU1 has improved both energy supply (−12%) and greenhouse gas emissions (−22%);
- EU2 has improved both energy supply (−17%) and greenhouse gas emissions (−24%);
- EU3 and EU4 present discontinuous trends and lower improvements in the time range considered: −5% for energy and −15% for emissions.

In summary, the group with higher $TPES_{pc}$ also presents higher HDI^*. On the contrary, GHG emissions per capita do not present this behavior.

3.2. Case Study B: Comparison among European Union and Other Countries

The aim of this case study is to compare the whole European Union (named EU in the next figures) to other countries in other continents: one in North America (United States of America), one in South America (Brazil) and one in Asia (Japan). It would certainly have been interesting to include other countries too, such as China and India. Unfortunately, no meaningful PISA data are available for China (only available from 2018 and for the following Chinese macro regions: Beijing, Shanghai, Jiangsu and Zhejiang), while this assessment has not yet been performed in India. In Figure 6, the government education spending of the EU and the other countries are reported.

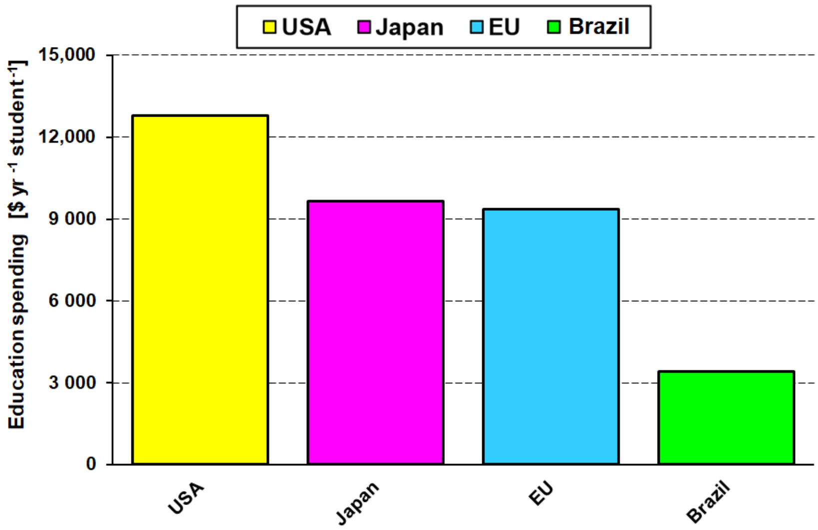

Figure 6. Case Study B. Government expenditures on education in the European Union and in the other analyzed countries. The expenditures are referred to the percentage of GDP for primary and lower secondary education divided by the number of students involved in that level of education.

In Figure 7, the United Nations Education Index EI_{UN} and its two components are represented. For I_{MYS}, a higher education spending always corresponds to a long schooling time. On the other hand, in relation to I_{EYS}, it can be pointed out that EU has the highest value, while Japan has the lowest value, close to the Brazil one. Considering the EI_{UN}, the US value is the best, while the Brazil one is the worst.

In Figure 8, a comparison about the OECD PISA information is proposed. US has the best results for I_{Rdn}, Japan has the best results for I_{Mth} and I_{Sci}, Brazil has the worst values in all disciplines and a great gap can be observed between Brazil and the other countries. For the Education Index, EI_{OP}, the best values are for Japan, and it is a remarkable result if compared with its education spending. The lower values of Brazil are justified by its low education spending.

The whole Education Index, Equation (11), has been calculated and then included into the new Human Development Index, Equation (12). In Figure 9, there are both classical HDI and the new HDI^*. Moreover, these indexes have been calculated for all the available PISA data, in the time range 2006–2018. For the USA, EU and Brazil the HDI^* values are always smaller than the HDI ones, in every year; on the contrary, for Japan, HDI and HDI^* are very close, and it is the only case in which HDI^* is greater the HDI (2009 and 2012). HDI presents the higher values for the USA. On the contrary, Japan presents the higher values of HDI^*, due to its good results in PISA scores. For all countries, the trends are almost always increasing over time.

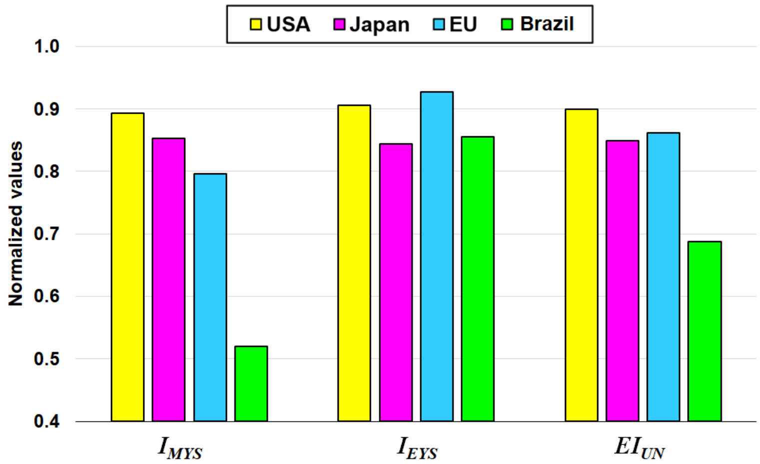

Figure 7. Case Study B. United Nations Education Index, EI_{UN}, and its components: I_{MYS} (normalized Mean Years of Schooling), I_{EYS} (normalized Expected Years of Schooling). This data are referred to the last year available for the OECD PISA assessment (2018). UNs data are available in Refs [56–58].

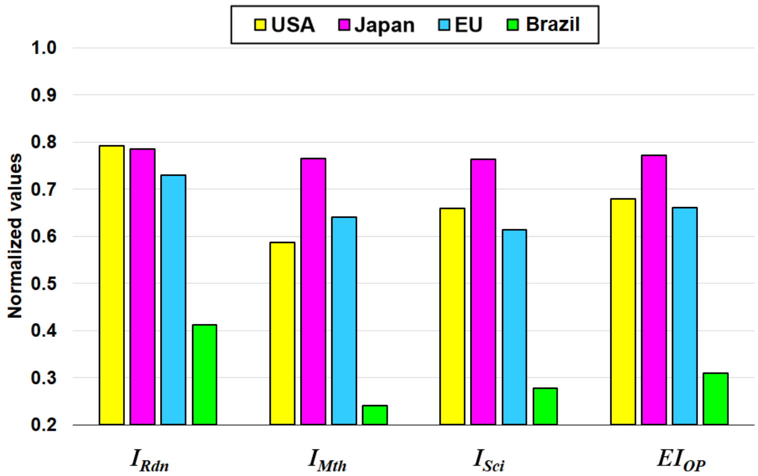

Figure 8. Case Study B. OECD PISA Indexes: I_{Rdn} is the normalized score in Reading, calculated by using Equation (7), I_{Mth} is the normalized score in Mathematics, calculated by using Equation (8), I_{Sci} is the normalized score in Sciences, calculated by using Equation (9), and EI_{OP} is the OECD PISA Education Index, calculated by using Equation (10). Raw data are available in Refs [49,50]. Data are referred to the last year available for the OECD PISA assessment (2018).

In Figure 10, the energy [65], and environmental [66] indicators are analyzed in relation to the HDI^*, for all the available data. Additionally, countries with the highest education spending can be highlighted to have a high $TPES_{pc}$, too. Analyzing the different countries, it can be pointed out that Japan achieved the best HDI^* value, with a reduction in energy requirement (−17%) without any reduction in GHG emissions, in the time range 2006–2018. EU has had a reduction both in energy (−13%) and in GHG emissions (−21%). Japan and EU have comparable values of $TPES_{pc}$ and GHG_{pc}, but Japan presents a higher HDI^*. The USA reduced energy (−12%) and GHG emissions (−16%), even if the USA presents a double value of $TPES_{pc}$ in comparison to EU and Japan values; consequently, the USA has a lot of room for improvement in relation to the possible reduction of $TPES_{pc}$ and GHG_{pc}. In comparison to the other countries, Brazil has the lowest $TPES_{pc}$, but also the lowest HDI^*. It has increased its HDI^* over time, but with an energy increase (+15%); moreover, Brazil has a peculiar GHG trend: there is a strong reduction in emissions (−36%), and, in relation to Figure 5, a sharp step between 2009 and 2012 can be shown in relation to the reduction of deforestation [67].

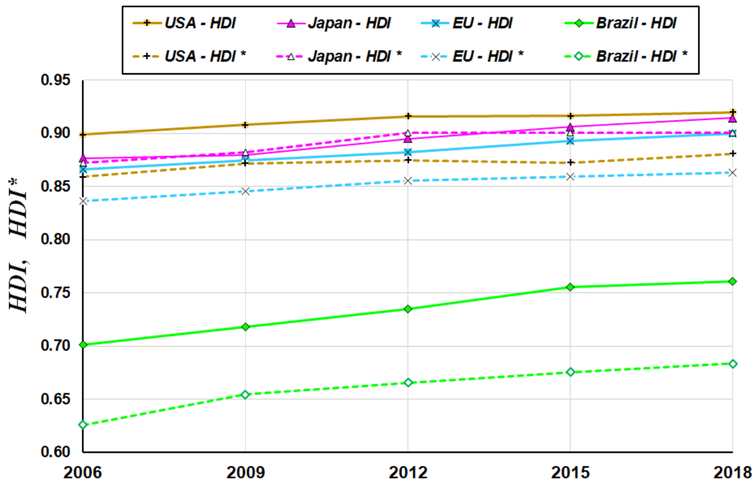

Figure 9. Case Study B. Comparison among European Union and other countries: HDI and HDI^* results. All the years in which the PISA tests were carried out are reported (2006, 2009, 2012, 2015, 2018).

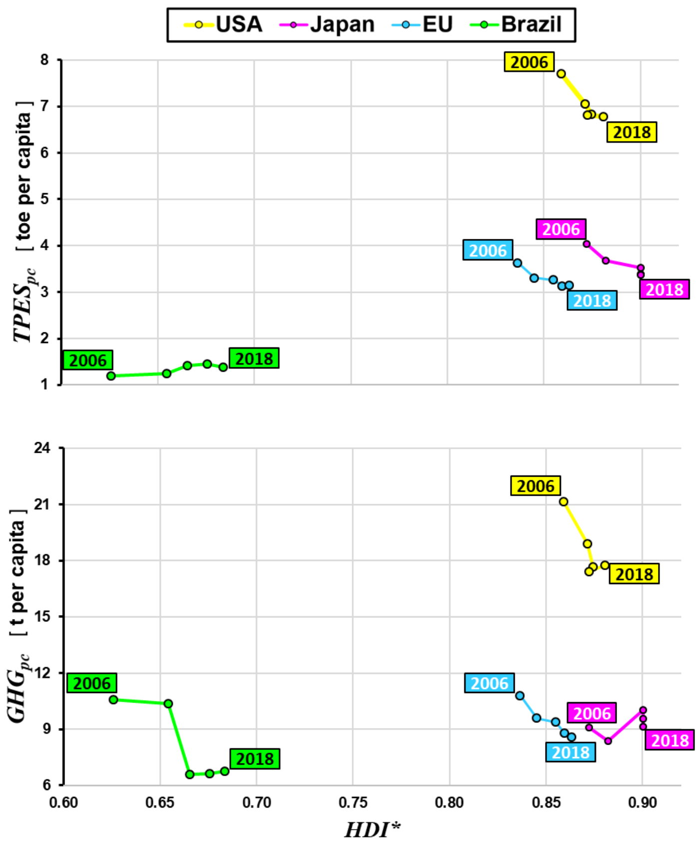

Figure 10. Case Study B. Comparison among European Union and the other countries: $TPES_{pc}$ and GHG_{pc} versus HDI^*. All the years in which the PISA tests were carried out are reported (2006, 2009, 2012, 2015, 2018).

4. Discussion and Conclusions

The aim of this paper is to introduce the evaluation of the abilities of students in relation to sustainable development into the United Nations' Education Index. Indeed, the UN's Education Index, EI_{UN}, is a quantity more related to social aspects than to the pupil's knowledge and skills. However, the sustainable development requires the introduction and use of new technologies and the related abilities for their use. It points out the key role of technical skills, of the adaptability of the workers in relation to new approaches to job, the propensity for innovation, and the individual contribution to it from any worker. The HDI does not measure these skills. Thus, it can be improved by considering also the measurement of the new workers skills. To do so, the OECD PISA results are considered, because of PISA is a comprehensive and accurate international assessment of student learning outcomes [48]. Moreover, this assessment has not been designed to test the knowledge levels of any student, but to extrapolate their abilities in relation to their knowledge. Thus, it is a comprehensive test, on which students exploit their abilities *at work*, related to their knowledge and skills for specific issues. This is the main requirement to the citizens of tomorrow. Moreover, PISA results are useful for policy makers to assess both the quality, and equity of learning outcomes attained by the 15-year-old students [42]. "Teaching and learning are the mental activity of grasping a new subject as something familiar" [68], building the personal body of knowledge. In sustainable societies, education evolution is an example of human evolution itself. Moreover, it has been highlighted that higher education must include training in sustainability disciplines [69], and Mathematics plays a key role in the achievement of the Sustainable Development Goals [70–72].

The OECD PISA assessment considers student's skills in Reading, Mathematics, and Sciences. These subjects can be interpreted in a general way as follows: Reading allows students to make any text intelligible, Mathematics allows pupils to make a logical attempt to any problem towards the problem solving, and Science gives the fundamental background to technical knowledge and applications. These are all essential aspects for the actual and next generations to allow us to build sustainable societies, in which all citizens play an essential role [73]. New solutions and technologies will be needed, not only to mitigate the anthropic impact on the environment, but also to find solutions in the context of adaptation to the consequences of the anthropic activities themselves. Thus, knowledge, problem solving, understanding of sciences, and mathematical skills represent fundamental keys to support actions towards more sustainable societies [74–76]. These abilities will be needed by all the citizens in the near future, together with trans-disciplinary knowledge and soft skills [77,78]. Indeed, PISA project does not consider all the characteristics of the human growth driven by education, e.g., creativity, critical thinking, ethics, freedom, etc. [79]. However, to the aim of this paper, a tool for quantitative evaluation is needed; PISA summarizes only a few topics of education, but the result is obtained by a unified approach for a large number of countries. This allows us to develop our analysis, although all the PISA project limits.

As all International Large-Scale Assessments (ILSAs), PISA has some limitations [80]: (i) it is a cross-sectional study, which measures educational outcomes at one point in time for a specific population; (ii) it is designed to reflect the educational results and relationships with background information within the education systems and not the single student's results; (iii) its content domains can not be considered exhaustive as concerns what is taught by the education systems. In particular, some criticisms on the methodology of the PISA assessment have been pointed out, i.e., sampling participants, achievement estimation model, measuring trends, and commercial interests [46,47,81–83]. As concerns the evaluation model, the OECD's methodological choices in the creation of data have been highlighted not to always be explicit and clear [84,85], and some issues have been reported on the scaling model for the final scores [86]. Thus, in order to allow researchers to analyze and improve the PISA project methodology, all rough data and procedures should be open source and clearly defined.

Nevertheless, actually, PISA results in the largest available international educational test, and it is considered unique, because it is more related to the student's abilities in relation to the use of their knowledge in every day life context [87]. Moreover, the same assessment is carried out in 79 countries, belonging to all continents, with the opportunity to use and compare them. Furthermore, this project is also being implemented for low and middle income countries with the PISA for Development (PISA-D). Thus, despite all the limits and criticisms related to this assessment, it actually results in a useful tool in the context of international education assessment.

In this study, some other considerations have emerged. They can be summarized as:

- Education spending and expected years of schooling time result as uncorrelated;
- In the EU area, mathematical and scientific abilities are related to the education spending, while reading abilities are independent from the education spending;
- On the contrary, considering countries of other continents, this correlation between mathematical and scientific skills with education spending does not emerge;
- In all the considered cases, a spending threshold emerges in relation to the PISA scores; indeed, below this threshold the PISA grades reduce sharply;
- The HDI^* maintains the same information of HDI, but it also takes into account the outcomes of the pupil's education pathway, in the disciplines assessed by the PISA assessment. The larger number of analyzed cases presents HDI^* values lower than the HDI, because the new Education Index proposed, EI^*, assumes lower values than the United Nations Education Index EI_{UN}, due to its information on pupil's outcomes;
- The increase in education spending does not always correspond to a higher HDI^*. For example, Japan was found to have the best HDI^* with a lower education spending than the USA.
- Countries with higher education spending present both higher primary energy supply and greenhouse gas emissions.

In relation to these first results, some future developments can be outlined:

i OECD PISA highlights the outcomes of 15-year-old students, but subsequent school cycles also deserve to be monitored, both in terms of education spending and student results;
ii It would be useful to understand the share of this spending for each country, e.g., number of teachers and their salaries, faculty refresher courses, ICT equipment, school infrastructures, etc.;
iii The temporal effect should be deeply evaluated: any change in education spending determines long-term effects, and its time trend.

In summary, the results of this paper highlight that sustainable development requires technical abilities for future workers, because of the more advanced technologies involved in any sustainable activity. Thus, it is clear that these abilities can be acquired and improved only by a deep background, which can be internalized only spending a long time in discussions, reflections, and reasoning. This can be done in a stimulating, multidisciplinary, creative and collaborative environment, as the schooling time can represent. Indeed, during this time, pupils can grow as people, human beings, increasing their relationship skills, their creative thinking, their emotional management, etc., in a continuous learning–teaching process through the different disciplines. In this context, Mathematics and Sciences represent a resource for pupils' future job placement, related to sustainable development, but also to the context of the problem solving approach of teaching. This allows pupils to realize themselves in their future work life, which is a facet of a person's life. Thus, in order to develop our analysis on this topic, a measurement tool was necessary to compare the greatest number of countries. OECD PISA represents a useful tool for our analysis, despite its limits. Nevertheless, the considerations of our analysis could open the way to approaches and studies on the possible improvements of the OECD PISA assessment, but also to the teaching of Mathematics and Sciences in the context of education, also in relation to the requirements of sustainable development, fundamental to preserve also our natural environment just for the future generation, which are pupils today.

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