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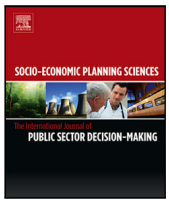

International differences in educational equity: An assessment using the Benefit of the Doubt model

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ABSTRACT

Educational equity is a key tool to promote countries' social and economic development and has become a central issue in international policy agendas. Since equity is multidimensional in nature and a complex process, a proper assessment of performance in terms of equity is a demanding task that requires aggregating several individual indicators to obtain a synthetic and simplified vision. This research aim to fill this gap by providing a synthetic measure to carry out a comprehensive and fair comparison of the degree of equity of the OECD educational systems. In particular, we use a robust directional Benefit of the Doubt (BoD) model to construct an Equity Composite Indicator, which allows us to benchmark the OECD educational systems in terms of equity based on a single criterion, considering its multiple dimensions and respecting the different priorities and particularities of the educational systems. The results find significant differences in equity among OECD educational systems. Furthermore, the empirical analysis reinforces the hypothesis that educational equity is a multidimensional concept, requiring the inclusion of all dimensions in the comparative analysis. This research provides a new approach that can be used not only to assess the evolution of educational equity across countries, but also to model its relationship with other economic variables. The proposed model could be useful in helping policymakers understand and improve educational equity in practice, as well as evaluate the impact of public policies.

1. Introduction

The quality formation of human capital has a proven positive impact on the future well-being of individuals and on the countries' economic development and growth [1–3]. More and better-educated individuals are more productive, which allows them to have better conditions of access to the labor market, and in turn, allows them to have higher wages and job satisfaction, social promotion, health and well-being throughout their life cycle [4,5]. Moreover, quality education produces numerous positive externalities in a society (e.g., development of democratic values, citizen participation and social inclusion, etc.), and it is thus one of the most powerful tools to reduce social and economic inequalities in society [6–8]. Then, a quality educational system requires not only obtaining good academic results from students, but also achieving them in an equitable way. That is, to provide equal opportunities to their students, where everyone can access a quality education and where their academic results depend on their abilities and effort, and not on the circumstances defined by their social, economic and cultural background [9–11].

However, international evidence showed that the family socioeconomic component continues to be one of the fundamental determinants of the educational success of students, even in developed countries [12,13]. This has been further evidenced with the recent health crisis, where the experienced school closures have had a very unequal impact on students from different family contexts [14]. As a consequence, educational equity remains a transcendental challenge for the development of societies. Within the framework of the 2030 Agenda, its relevance is made explicit in the fourth sustainable development goal (SDG-4),[1] which advocates the need of inclusive and quality education. In this context, the evaluation of education systems in terms of equity has become a central issue in the policy agendas internationally. Cross-country comparisons of education systems in terms of educational

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[1] https://sdgs.un.org/goals/goal4

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equity permits not only to benchmark them, but also, and more importantly, to identify the potential improvements, the best practices and the most effective policies.

The growing interest and concern for the study of educational equity in terms of achievement is also reflected in the information provided by international large-scale assessments (ILSAs), mainly in the *Program for International Student Assessment* (PISA), implemented by the Organization for Economic Co-operation and Development (OECD) in the late 1990s. PISA assesses secondary students' performance (aged between 15 and 16 years old) in three core competencies: mathematics, reading and science. In addition to those achievement measures, the database also provides information about the students' family background and the school environment. These evaluations have been carried out since 2000 (every three years), however, as of the 2006 edition, the OECD begins to produce a multiplicity of individual indicators that reflect different dimensions related to educational equity, such as the influence of socioeconomic status on the academic results of students, school segregation, or resilience, among others [15–20]. The international evidence reveals two key facts: (i) there exists notable differences in terms of educational equity between educational systems, (ii) the results differ substantively and qualitatively according to the indicator used [21–24]. In fact, it is almost always possible to find an indicator for each education system that positions it relatively well in the international comparison. Consequently, it is not possible to obtain a global picture or draw general conclusions about the performance of each educational system or its evolution over time in terms of equity. Then, a proper assessment of performance in terms of equity requires aggregating the individual indicators to obtain a synthetic and simplified vision, based on all the information available, yet exhaustive. This is a demanding task since equity is multidimensional in nature and a complex process, covering diverse approaches ranging from providing universal access to education to mitigating the effect of socioeconomic background on academic achievements. This is likely one of the main reasons why equity has been an under-researched issue in education.

This research aims to fill this gap by providing a comprehensive and fair comparison of equity performance between the OECD educational systems using a synthetic measure -composite indicator (CI hereafter). To do this, we aggregate the multiple individual indicators available in international educational databases [25,26] using various extensions of the *Benefit of the Doubt* (BoD) model [27]. This approach has gained notable popularity in recent years as a tool for constructing composite indicators in various areas such as competitiveness, social welfare, environmental sustainability or well-being in OECD countries [26,28–31]. However, its application in the field of education to assess the performance of educational systems at the country level has been very limited. The majority of studies in education using non-parametric frontier methods (Data Envelopment Analysis or some extension) at the country level have been focused on measuring their technical efficiency where students' academic achievement measured by test scores are the most common outputs (see [32] for a detailed literature review). Only a few recent studies focused on cross-country comparisons of educational performance using composite indicators and including at least one indicator related to equity [33–38].[2] All of these previous studies are focused on European or OECD countries, mainly because of the availability of comparable data from international large-scale assessments (e.g. PISA, TIMSS and PIRLS) and from international databases (OECD, Eurostat and UNESCO). Stumbriene et al. [33], Camanho et al. [37] assessed the performance of European education systems in the light of Europe 2020 strategy. Stumbriene et al. [35] focused on measuring the efficiency and effectiveness of primary education in post-socialist and old democracy EU members states. Dominguez-Gil et al. [36] employed a multiplicative composite indicator to evaluate educational systems in OECD countries and later, Segovia-González and Contreras [38] applied the same approach to compare the performance of male and female students in European educational systems. The closest work to our is [34] who evaluated the efficiency and effectiveness of European countries in terms of educational inclusion, fairness and inequality.

This paper is framed within this line of research, although the aim and the methodological approach are qualitatively different in at least two directions. First, none of them provide a multidimensional composite indicator exclusively focused on measuring equity since they include in their analysis other dimensions as PISA scores or inequality (variability in scores) to construct the CI. Second, none of previous works take into account one of the criticisms that international comparisons of countries usually receive through the use of composite indicators: the lack of consideration of the economic and social heterogeneity that may exist between countries [39,40]. To address this limitation, we incorporate in our analysis a conditional version of the BoD model which allows us to take into account different socioeconomic characteristics (i.e. contextual factors) of the education systems under analysis to perform a "fairer" comparison.

Our research contributes to the literature in several ways. First, it contributes to the benchmarking of countries based on equity performance which has been an overlooked issue in education research. Second, it contributes to the understanding of the equity concept by discussing and considering in the comparison its multiple dimensions. Our findings reveal that the three dimensions of educational equity are complementary, and the insights on system performance in each of these dimensions can be highly valuable for policymakers in designing targeted educational policies. To effectively compare educational equity across different education systems, it is crucial to incorporate all dimensions into the analysis. Finally, this is the first research including regional educational systems in the international performance comparison in terms of equity. This approach is essential for countries with a federal structure, where educational competencies are managed by regional governments. Indeed, the empirical analysis reveals that in these countries, equity indicators often exhibit significant heterogeneity across regions, with notable disparities from the national average. In such cases, our approach enables to capture these disparities and to perform more accurate comparisons that reflect the organization of their educational systems.

The remainder of the paper is organized as follows. Section 2 describes the equity conceptual framework, including the definition of the dimensions of equity, the indicators selected to construct the composite indicator and the contextual variables included in the analysis. Section 3 presents the methodological approach. Section 4 discusses the results regarding the performance of the OECD educational systems in terms of equity. The last section is devoted to the conclusions of the study.

2. Equity conceptual framework: dimensions and indicators

Although there are various definitions of educational equity, one of the most widely accepted internationally is the one established by the OECD, which defines a system as equitable if: it enables all individuals to reach at least a basic minimum level of skills ("inclusion") and it ensures that personal or social circumstances such as gender, ethnic origin or family background, are not obstacles to achieving educational potential ("fairness") [16,41,42]. This is the general conceptual framework we will adopt in this study, as our focus is on measuring educational equity within OECD education systems.

Building on this framework, we identify three dimensions that enable the operational measurement of educational equity: (i) Inclusion, (ii) School segregation, and (iii) Equality of opportunities. *Inclusion* corresponds to the first principle of equity outlined earlier, and attempts to capture the capacity of the educational system not only to guarantee universal access to education at compulsory stages, but also to ensure that all students reach a minimum standard of proficiency [43]. The latter two dimensions are linked to the fairness

[2] See Table 10 in the Appendix for an overview of the these works.

principle, which concerns the capacity of educational systems to address and reduce existing socioeconomic disparities, approached from two distinct perspectives. The dimension of *school segregation* refers to the uneven distribution of students from different backgrounds across schools [44]. Socioeconomic school segregation occurs when socioeconomically advantaged students are concentrated in certain schools, while students from disadvantaged backgrounds are clustered in others, resulting in unequal educational environments. Finally, the dimension of *equality of opportunities* is closely linked to the definition proposed by Roemer [9]. According to that, students' educational success should depend solely on their effort and abilities, but not on their personal or family circumstances and educational systems must provide all students with the same opportunities for access to quality education. Although both school segregation and equality of opportunities are related to fairness, they address different aspects, and consequently, the educational policies aimed at promoting each one differ. Regarding segregation, policies designed to reduce it should focus on improving access to schools and ensuring a more equitable distribution of students across schools. Conversely, policies designed to promote equality of opportunity are typically oriented toward supporting students from disadvantaged backgrounds, providing targeted interventions to mitigate the disadvantages associated with their socioeconomic starting points.

Since the three dimensions capture relevant complementary aspects of equity, in a first stage we compute a composite indicator for each of them independently, and finally, we aggregate them into one synthetic measure of educational equity: the Equity Composite Indicator. This enables us to explore and understand the relevance of each dimension in terms of equity and to identify different profiles within the sample of the OECD countries, with different policy implications.

Once the dimensions are defined, it is essential to select the individual indicators to be included within each dimension to compute the composite indicator. This selection is one of the most relevant decisions in the process of constructing composite indicators [26]. In this regard, a wide range of indicators can be found in the literature to measure each of the above-mentioned dimensions. Due to the limited sample size (OECD educational systems), we tried to be parsimonious in the selection of the indicators, including only those that provide relevant and non-redundant information. In order to ensure the comparability across the indicators, all data come from or have been estimated using the information provided by the PISA 2018 database. Although PISA assesses students' performance in mathematics, reading, and science, each wave focuses on one of these domains. In this study, to estimate the equity indicators, we have focused solely on students' reading performance, as it was the main domain assessed in PISA 2018 [45]. Additionally, reading is a transversal skill critical to learning in all domains, making it particularly relevant for assessing equity [46].

We include in the analysis 34 OECD countries and the Canadian and Spanish regions (9 and 17 regions, respectively)[3] participating in PISA 2018. The analysis focuses on OECD education systems to ensure a sample of well-documented systems subject to comparable standards. Some OECD countries were excluded from the analysis due to the lack of available data for one or more indicators, which compromised the comparability of the results. Regarding Canada and Spain countries, regional governments are responsible for the education process and the management of educational resources.[4] Accordingly, assessing performance in these two countries is more appropriate at the regional level rather than the national level. This approach ensures that the analysis captures the actual context of education delivery in these countries and highlights variations across regions. Although there are other OECD countries with decentralized educational systems, we only include regions from Canada and Spain since they were the only two countries with representative results for all their regions. For example, Italy or Belgium also oversample the schools/students included in the evaluation to obtain representative data but only for some regions. Moreover, these regions are not always equivalent to the regional government responsible for the educational policy.

2.1. Individual indicators

In the following we describe the individual indicators we have selected to capture the three dimensions defined above, guided by the existent literature in the field and the availability of data. Fig. 1 displays each dimension along with its indicators grouped into the global Equity Composite Indicator.

For the *Inclusion* dimension, two indicators were selected. As a measure of access to education we use the *enrollment rate* reported by PISA, computed as the percentage of 15-year-old students enrolled in level 7 or above out of the total 15-year-old population. Second, to measure whether students reach a minimum standard of proficiency or not, we include the *percentage of students scoring below level 2 in reading PISA score* (defined as the basic proficiency level by the OECD). Students' performance is measured on a continuous scale with a mean score of 500 and a standard deviation of 100 for the sample of OECD countries.[5] In addition, the scores obtained in each competency are grouped into different proficiency levels (usually six) which attempt to represent the students' skills and knowledge, considering level 2 the minimum threshold that will enable students to participate effectively and productively in life [49]. In this respect, the lower the percentage of low-achieving students, the greater the inclusiveness of the educational system (undesirable indicator). This measure has gained prominence in recent years, being used both to set the objectives of Europe 2020 strategy and the 4th Sustainable Development Goal referred to the quality of education, as well as a benchmark adopted by the European Union in the strategic framework for European cooperation in education and training [50]. International evidence shows that the economic benefits of achieving universal basic skills (proficiency level 2 in PISA tests) could be substantive [5]. Consequently, this indicator has been widely used in recent previous research to compare the inclusion in education across countries [33,36–38].

School segregation is the second dimension of equity observed. Three complementary indicators were chosen to capture the school segregation from different perspectives. The first is the *Index of Social Inclusion* (ISI) that measures the degree to which students from different socioeconomic backgrounds attend the same school or the degree to which different schools have different socioeconomic profiles. The index is defined as the percentage of the total variation of students' socioeconomic backgrounds observed within schools, as opposed to between schools[6]

[3] We exclude for the analysis the Prince Edward Island Canadian region and Ceuta and Melilla Spanish regions since they are very atypical regions and cannot be compared with rest of the sample.

[4] In Canada and Spain, the Constitution of 1867 and the Constitution of 1978, respectively, establish education as a responsibility of the provinces or autonomous communities (referred to as regions from now on), resulting in highly decentralized education systems. This framework was further formalized by specific laws, granting regions substantial authority over key educational policies. This regional management model justifies analyzing data at the regional level for these countries, as educational policies and outcomes can vary significantly between regions.

[5] For each competency, cognitive skills or abilities are assessed using ten plausible values rather than a single score. The plausible values are drawn randomly from students' distribution of scores, which are estimated by means of Item Response Theory [47, 1980]. These plausible values are considered a representation of the range of students' abilities and should be used in their entirety for the estimation of any population statistic [48].

[6] In this research, the socioeconomic background of the student is measured by the so-called index of economic, social and cultural status (ESCS from now on), provided by PISA and composed of the highest educational and occupational level of either parent and an indicator of books and cultural possessions at home. Depending on the values in this index, PISA defines students as socioeconomically disadvantaged (advantaged) when they are in the bottom (top) quartile of the ESCS distribution in their country or region.

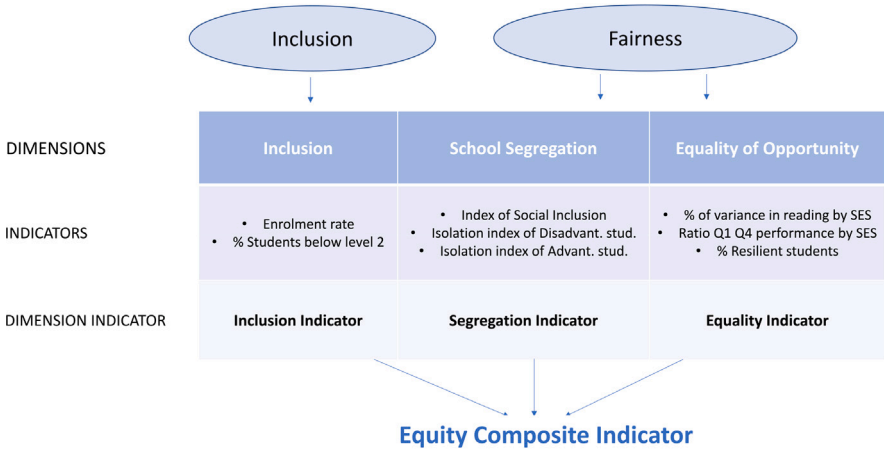

Fig. 1. Dimensions and indicators for the equity composite indicator.

as follows:

$$ISI = \left(1 - \frac{\sigma_b^2}{\sigma_b^2 + \sigma_w^2}\right) \times 100$$

where σ_b^2 denotes the between-school variation in student socio-economic status and σ_w^2 stands for the within-school variation in student socio-economic status. This index takes values between 0 and 100. A higher value of the index of social inclusion means that there is less heterogeneity in socioeconomic terms between students in different schools than among students in the same school (i.e. less segregation and more equitable system). In PISA 2018 the OECD also provided two additional indicators related to school segregation by socioeconomic status: the *Isolation Index of Disadvantaged students* and the *Isolation Index of Advantaged students*. We include these two indicators, which are complementary to the former ISI and each other, allowing for an analysis of whether social segregation between schools is better explained "at the bottom" by the clustering of disadvantaged students in certain schools, or "at the top" by the concentration of advantaged students in others, respectively [20,51]. These indices are estimated as

$$I = 1 - \frac{\sum_{j=1}^{J} \frac{n_j^a}{N^a} \frac{(1-n_j^a)}{n_j}}{1 - p^a}$$

where n_j^a represents the number of disadvantaged (advantaged) students in school j, N^a corresponds to the total population of disadvantaged (advantaged) students in the country or region, n_j denotes the total number of students in school j, and p^a is defined as the proportion of disadvantaged (advantaged) students in the population N. These indices range from 0 (no segregation) to 1 (full segregation). A higher value of the index means that disadvantaged (advantaged) students are more often isolated in specific schools with classmates from similar backgrounds, indicating that the educational system is more segregated (undesirable outcomes indicators). From an equity point of view, it is essential to target school segregation by paying special attention to disadvantaged students because if they also attend schools with a lower socioeconomic profile, they face a double disadvantage arising from potential learning difficulties both at home and at school [19].

Finally, the third equity dimension analyzed is the *Equality of opportunity*, which is measured by examining the degree to which students' educational achievement are influenced by their socioeconomic background (ESCS). To do that, we opted for the following three indicators. First, we include the *percentage of variance in reading score explained by students' socioeconomic status*. This value is provided by the R^2 obtained when regressing students' reading score on ESCS index. This indicator has been largely used in the literature of equality of opportunities in education [12,52] to capture the extent to which educational systems are able to mitigate the effect of students' socioeconomic status on their potential performance. It is therefore inversely related to the equality of opportunities, i.e. the higher the R^2, the more unequal the educational system (undesirable indicator). Second, we estimated the percentage of students below level 2 in reading at the top quartile and in the bottom quartile of the ESCS distribution. We then computed the *Parity Index* which is computed by dividing the percentage of low achievers in reading in the bottom quartile of the ESCS distribution by the percentage of low achievers in reading in the top quartile of the ESCS distribution. The higher the Parity Index, the higher the gap between the socio-economically disadvantaged and advantaged students, and therefore the more unequal the educational system is considered (undesirable indicator) [53,54]. The last indicator for this equity dimension is the *Percentage of Resilient students*. According to the literature, a student who manages to overcome their socioeconomic obstacles and achieves excellent results, i.e. a student who does well academically despite coming from unfavorable backgrounds, is known as resilient [55]. We have followed the definition of national academic resilience proposed by the [19]: resilients are those socioeconomically disadvantaged students (in the bottom quartile of the ESCS distribution) in their own countries (regions) who score in the top quarter of performance in reading among students in their own country (region). This indicator has also become very popular in the economics of education literature [56] and has been included in previous research to compare countries performance in terms of fairness [35,36,38].

Table 1 summarizes the selected indicators for each dimension and Table 2 provides the main descriptive statistics of all indicators included in the analysis for the 60 OECD education systems.[7,8] We can corroborate that differences across educational systems vary considerably depending on the indicator. On average, educational systems are doing pretty well regarding enrollment rate. On the contrary, the major heterogeneities across education systems are related to the percentage of students performing below level 2, both isolation indicators and the effect of socioeconomic status on achievement (R^2).

2.2. Contextual variables

To perform a "fairer" comparison between education systems with heterogeneous characteristics, we account for differences in socioeconomic characteristics (contextual variables) across the education systems under analysis. These contextual or environmental factors are

[7] It should be noted that, in those cases where the indicator was not provided by the PISA 2018 report, it has been calculated taking into account the ten plausible values and the correct application of the sample weights and their replications using the REPEST command provided by STATA© [57].

[8] In Table 11 in the Appendix we provide the database with the individual indicators for the 60 OECD education systems.

Table 1
Indicators for the construction of the CI for each dimension of educational equity.

Indicators	Description
1st Dimension: Inclusion	
Enrollment rate	The percentage of the 15-year-old population who were enrolled in level 7 or above.
% Students below level 2[a]	The percentage of PISA students who scored below level 2 in reading.
2nd Dimension: School segregation	
Index of Social Inclusion	The percentage of the total variation of students' socio-economic backgrounds observed within schools, as opposed to between schools.
Isolation index of Disadvant. stud.[a]	It measures the concentration of socio-economically disadvantaged students in a limited number of schools.
Isolation index of Advant. stud.[a]	It measures the concentration of socio-economically advantaged students in a limited number of schools.
3rd Dimension: Equality of opportunities	
Effect of ESCS on reading (R^2)[a]	The average percentage of variation in reading achievement that is explained by students' socio-economic status.
ESCS Parity Index for low-achievers[a]	Ratio between the percentage of low achievers in the bottom quartile of ESCS and the percentage in the top quartile of the ESCS.
% Resilient students	The percentage of pupils who, being among the socio-economically disadvantaged in their country (region), score in the top quarter of the reading performance among students in their own country (region).

[a] Note: (a) Undesirable indicators: lower values represent more equitable educational systems.

Table 2
Descriptive statistics of indicators considered in our analysis.

Dimension/Indicator	Obs	Mean	SD	Min	Max
Inclusion					
Enrollment rate	60	96.17	4.83	75.38	100
% Students below level 2[a]	60	21.50	6.99	10.96	49.72
School segregation					
Index of Social inclusion	60	79.08	7.86	56.30	93.00
Isolation index of Disadvant. stud.[a]	60	0.15	0.05	0.08	0.27
Isolation index of Advant. stud.[a]	60	0.17	0.06	0.07	0.37
Equality of opportunities					
Effect of ESCS on reading (R^2)[a]	60	10.37	3.75	4.03	19.06
Parity Index low-achievers by ESCS[a]	60	3.33	0.91	1.91	5.99
% Resilient students	60	12.71	2.58	7.24	20.50

[a] Note: (a) Undesirable indicators: lower values represent more equitable educational systems.

different from the equity indicators, since they are not under the control of the educational authorities/policymakers in each country. However, they can hinder or make it more difficult to achieve an equitable education system.

We include the following three different contextual variables.[9] The first contextual variable is the Gini Index, which measures the extent to which the distribution of income among individuals or households within an economy deviates from a perfectly equal distribution (income inequality). The Gini index measures the area between the Lorenz curve[10] and a hypothetical line of absolute equality, expressed as a percentage of the maximum area under the line. Thus a Gini index of 0 represents perfect equality, while an index of 100 implies perfect inequality.[11] Research in OECD countries found that income inequality has a negative impact not only on economic growth but also on skills developments (e.g. years of schooling, skills proficiency), mainly among individuals from low-socioeconomic backgrounds [58,59]. Income inequality generates significant disparities in educational achievement by family background that can be observed across the developed world [60]. Additionally, income inequality is closely related to social mobility across generations. Indeed, much empirical research finds that countries with higher levels of income inequality tend to show lower levels of social mobility across generations, with more egalitarian countries having higher levels of social mobility (Nordic countries) than more unequal countries (Italy, the United Kingdom and the United States). Research on the mechanisms through which income inequality influences social mobility reveals that greater income inequality limits education opportunities for talented yet underprivileged individuals. In societies with higher income inequality, socioeconomically disadvantaged youth tend to perceive smaller-than-actual returns to investing in further education [19].

Second, we consider the share of population 25 to 64 years old with tertiary education (ISCED 2011 levels 5 to 8). The empirical literature has documented that one important reason of within country differences in educational attainment is family background. Since learning begets learning, initial differences in individual achievement at school due to parental education are likely to widen overtime. Since parental education is a circumstance beyond individual control, differences in outcomes generate inequality [61].

Finally, we include as a contextual variable the unemployment rate measured by the percentage of unemployed people over labor force (15–64 year old). The opportunity cost of staying in school depends on how easily young school leavers can find a job. Hence, a high unemployment rate is expected to decrease the dropout rates. However, high unemployment may have differential effects on dropout rates among different social groups. Disadvantaged youth seem to be more sensitive to the labor market conditions, as the opportunity costs of staying in school are more heavily felt by those in financial need. At the same time, disadvantaged children seem sensitive to the damaging effect of economic crises on the educational aspirations [62].

[9] We have also estimated the models including other contextual variables as the public expenditure in education per student, share of immigrant population and GDP per capita. However, they were not associated with equity in our analysis, then we decided not to include them in the research. Results are available upon request.

[10] A Lorenz curve plots the cumulative percentages of total income received against the cumulative number of recipients, starting with the poorest individual or household.

[11] The Gini index information was retrieved from the World bank data for OECD countries, the Spanish statistical Office (INE) for Spanish regions, and from the Statistics Canada (Canadian statistical office) for Canadian regions.

Table 3
Descriptive statistics of contextual variables considered in our analysis.

Contextual variables	Obs	Mean	SD	Min	Max
Gini index (Income inequality)	60	32.82	4.90	23.20	49.70
% of population with tertiary education	60	38.04	10.23	17.40	63.00
Unemployment rate	60	9.52	5.79	2.90	26.40

Table 3 summarizes the descriptive statistics of the selected contextual variables. As shown, there is considerable variation in the three socioeconomic contextual variables across the educational systems in the sample. This underscores the importance of incorporating the context in the analysis, since it could be very demanding for countries with very unfavorable context (such as the Latin American countries) to reach the level of equity of countries with a favorable context (such as the Nordic countries or Canada).

3. Methodology

In this research we measure and compare the performance in terms of equity of OECD educational systems by constructing a synthetic measure: the Equity Composite Indicator (ECI hereafter). To do that, we first use a "robust Directional Distance BoD model" (DD-BoD) to compute three independent composite indicators, one for each dimension: the *inclusion* CI, the *segregation* CI and the *Equality of Opportunities* (EOp hereafter) CI. Finally, we take the arithmetic average of these three CI to compute the global ECI, to allow for perfect substitution between dimensions [26,63]. Moreover, the arithmetic average does not penalize those countries with low performance in some dimension (in line with the nature of the BoD).

3.1. The BoD model

The Benefit of the Doubt (BoD) model is inspired by the Data Envelopment Analysis (DEA) methodology [64], introduced by Melyn and Moesen [65] and popularized by Cherchye et al. [27]. The BoD model can be formulated as an input-oriented DEA model under constant returns to scale (CRS), assuming a unique input equal to one for all evaluated Decision Making Unit (DMUs hereafter). The most attractive advantage of the BoD model for constructing composite indicators is that it does not require *a priori* information to establish the aggregation weights for each indicator but they are assigned endogenously for each education DMU, in such a way as to maximize its relative performance [66] as shown in (1):

$$\begin{aligned} CI_{j_0} = \max \quad & \sum_{r=1}^{s} y_{rj_0} w_{rj_0} \\ \text{s.t.} \quad & \sum_{r=1}^{s} y_{rj} w_{rj_0} \le 1, \qquad \text{for } j = 1, \dots, n \\ & w_{rj_0} \ge 0, \qquad \text{for } r = 1, \dots, s \end{aligned} \tag{1}$$

where y_{rj_0} denotes the observed indicator r within each equity dimension of the evaluated country j_0; y_{rj} denotes the observed indicator r of every country j in the dataset; n is the number of countries under analysis (n=60) and s signifies the number of indicators considered for each equity dimension. The first constraint in the model formulation is known as the *normalization* constraint, forcing the composite indicator CIj_0 to be maximized subject to an upper bound equal to one. The second constraint imposes the weights to be non-negative.

Thus, the model assigns higher (lower) weights to the individual indicators w_{rj_0} in which each DMU performs better (worse). The basic principle behind the BoD model (and hence its name), is that a relatively good performance of a DMU in an individual indicator implies that this dimension is relatively important for that DMU and should therefore have more importance than the rest to build the composite indicator. Another appealing property of the BoD composite indicator is that it is invariant to the unit of measure of the individual indicators, thus avoiding the need to standardize or homogenize the original individual indicators.

The CIj_0 value ranges between zero and one where the higher the value, the higher the performance of the evaluated country. If CIj_0 <1, it means that, even if evaluating the country under analysis by employing its most favorable weighting system, there is at least another country performing better in that equity dimension. Hence, it would mean that there is still room for improvement. If CIj_0 =1, then it denotes that the country under analysis is not outperformed in the evaluated dimension and it is considered as its own benchmark while using its most favorable weight system.

The advantage of using this approach is twofold: first, it allows to group together several aspects into one single indicator. Second, it ensures the fairness of the comparison, since each evaluated educational system is granted the "Benefit of the Doubt" in the assessment and the fairness of the comparison is ensured (for more details on the BoD approach, see e.g. [27,67,68]).

In the following, we present the different extensions we have adopted to the basic BoD to (i) deal with desirable and undesirable individual indicators (directional distance functions); (ii) to ensure that all individual indicators take part in the CI (weight-restrictions); and finally, (iii) to account for the heterogeneous socioeconomic conditions where educational systems operates (robust and conditional approach).

3.2. The robust and conditional directional distance BoD model

The first extension to the basic BoD model is regarding the inclusion of undesirable indicators. In the basic BoD framework, a higher value in a certain indicator denotes a better performance, i.e. to this extent the indicator can be labeled as "desirable". However, in this research, some of the indicators included in the analysis, e.g. the percentage of students below level 2, must be considered as undesirable indicators. While desirable indicators (e.g. resilient students) should be maximized, the undesirable indicators should be minimized. The inclusion of undesirable features in the construction of composite indicators is quite recent and it is associated with the performance measurement literature (for an extensive review, see [69,70]). In this research we follow a direct approach introduced by Zanella et al. [69] and advocated by Rogge et al. [68], where the BoD is formulated using directional distance functions [71]. This approach of the directional distance BoD (DD-BoD hereafter) redesigns the efficient frontier to avoid downward-sloping segments, with negative trade-off between desirable and undesirable outputs. In the context of education this assumption is more realistic, since it is possible to reduce the undesirable indicators without the need of reducing desirable ones. For example, an education system could reduce the impact of the student's socioeconomic status on their achievement at the same that it increases the percentage of resilient students. The CI related to each equity dimension including desirable and undesirable indicators is computed by solving the following optimization problem (DD-BoD) for each educational system j_0 under assessment:

$$\begin{aligned} \beta_{j_0} = \quad & \min \quad -\sum_{r=1}^{s} y_{rj_0} u_{rj_0} + \sum_{k=1}^{l} b_{kj_0} p_{kj_0} + v_{j_0} \\ \text{s.t.} \quad & \sum_{r=1}^{s} g_y u_{rj_0} + \sum_{k=1}^{l} g_b p_{kj_0} = 1 \\ & -\sum_{r=1}^{s} y_{rj} u_{rj_0} + \sum_{k=1}^{l} b_{kj} p_{kj_0} + v_{j_0} \ge 0 \qquad \text{for } j = 1, \dots, n \\ & v_{j_0} \in \Re \\ & u_{rj_0} \ge 0 \qquad \text{for } r = 1, \dots, s \\ & p_{kj_0} \ge 0 \qquad \text{for } k = 1, \dots, l \end{aligned} \tag{2}$$

where y_{rj_0} and b_{kj_0} respectively refer to the observed r desirable and k undesirable indicators of the evaluated educational system j_0; y_{rj} and b_{kj} respectively refer to the r desirable and k undesirable indicator of every educational system j in the dataset; n is the number of educational systems under analysis (n=60); and s and l respectively denote the number of desirable and undesirable indicators considered in this application. In this model, u_{rj_0} and p_{kj_0} respectively represent

the most favorable virtual weights for the r desirable and k undesirable indicator for the evaluated educational system j_0; and v_0 is associated with the weights of the unitary input. Note that weights are specific for each evaluated educational system. Finally, the vector $g = (-g_b, g_y)$ is called the directional distance vector, indicating the direction in which undesirable and desirable indicators should change. The negative values indicate that undesirable indicators should be constrained and positive values are associated with an expansion of desirable indicators. Then the factor β_{j_0} denotes the maximal expansion of desirable indicators and contraction of undesirable indicators that the education system j_0 can achieve simultaneously. The choice of the direction vector $g = (-g_b, g_y)$ is important as it might impact the optimal results. Several solutions have been proposed in the literature depending on the objectives pursued (see for example [68] for a discussion on different direction values and formats). When the direction vector is equal to $g = (-b_{kj_0}, y_{rj_0})$, i.e. the current values of the indicators for the DMU under assessment, the directional distance function is comparable with the Shephard's output distance function and the composite indicator of each unit j_0 can be obtained as $CI_{j_0} = 1/(1 + \beta_{j_0})$. The obtained score ranges between zero and one, where one denotes the greatest equity level in line with the basic BoD model. We will follow this specification of the direction vector where each educational system follows its own specific path for improvements.

As mentioned before, one of the greatest attractions of the BoD model lies in the fact that the weights of each indicator are determined specifically and endogenously for each educational system, maximizing the value of its CI. This great flexibility has also some drawbacks, as it enables to exclude from the construction of the CI those individual indicators in which the educational system under assessment had a very poor performance by assigning them a weight equal to zero. To avoid this result, the most intuitive (and popular) alternative in the framework of CI is to restrict the indicators' virtual weights (for a review, see for all [27,69,72]). In this research, we follow the formulation proposed by Zanella et al. [69] that allows to directly restrict the importance of each indicator in percentage terms, they are not DMU-specific and they are independent to the unit of measurement of the indicators. In our context, we are interested in avoiding zero weights, that is, we want to make sure that all the indicators within each educational equity dimension take part in the construction of the CI. To do so, we set a weight restriction on the minimum importance of each indicator, but we do not impose an upper bound. We follow the equal weight restrictions introduced in [33,73], where for each of the three CI we have set a lower bound equal to $\phi = 0.1/n$, where n is equal to the number of individual indicators included in the CI.

All the steps discussed so far are imperative for ensuring an increasing level of fairness in the equity evaluation across different educational systems. However, as we have discussed above, there is a last aspect that should not be overlooked, namely, the role of the operating context under which the educational systems are required to function. These factors impact not only the distribution of the composite indicator scores but also their achievable set, even though they are exogenous regarding the equity level and outside the purview of educational policy makers. Consequently, the composite indicator CI_{j_0} outlined so far has to be adjusted in a manner that it accounts for the differences in the environmental variables. To do this, we have adopted one of the most popular approach in the literature to deal with this situation, which is the "conditional" approach [74].

Furthermore, employing the knowledge from the "order-m" approach, the conditional analysis is carried out in combination with its robust version to reduce the impact of outlying observations, resulting from, for example, measurement errors and atypical observations. While we refer to [74–78], among others, for a more formal and comprehensive explanation of the technique, we summarize the robust conditional analysis implementation process and its basic intuition below.

To reduce the influence of the outlying observations, we run a Monte-Carlo algorithm that completes B calculation rounds (where B is large) for the computation of the robust composite indicator. In each b round ($b = 1, \ldots, B$), first m educational systems are drawn with replacement from the original sample of n units and then the m-sample "DD-BoD with weight restrictions" composite indicator $CI_{j_0}^{b,m}$ is computed. Finally, the robust composite indicator $CI_{j_0}^{m}$ is obtained as the arithmetic average of the B $CI_{j_0}^{b,m}$, as follows:

$$CI_{j_0}^{m} = \frac{1}{B}\sum_{b=1}^{B} CI_{j_0}^{b,m}$$

The educational system under review may not be included in its own reference set and may be considered a super-performing unit as a result of the subsampling procedure [79]. As a result, it is possible that $CI_{j_0}^{m}$ and $CI_{j_0}^{m,b}$ are greater than one. This might be interpreted as the educational system j_0 under review is more equitable in the examined dimension than the average reference sample of m educational systems.

To account for the diversity of educational systems represented by the z contextual factors, the Monte-Carlo simulation process remains unchanged, except for some modifications in the drawing phase. Based on an estimated kernel density function, the m educational systems are drawn with replacement and with a specific probability. The goal is to draw educational systems m that are more likely to be comparable to the educational system j_0 that is being evaluated (and less probable to differ from it). This ensures a higher degree of fairness when comparing the various educational systems under examination and allows for the calculation of the CI taking comparable background conditions into account:

$$CI_{j_0}^{m,z} = \frac{1}{B}\sum_{b=1}^{B} CI_{j_0}^{b,m,z}$$

In this case, when $CI_{j_0}^{m,z}$ score is greater than one, the evaluated educational system j_0 is more equitable than the average m educational systems with comparable background characteristics.

Finally, investigating the direction of the impact of contextual elements z on the CI (equity dimensions) is made possible by the conditional DD-BoD model technique. Our approach involves calculating the ratio of the robust unconditional to conditional CI measures, $R_{j_0} = CI_{j_0}^{b,m}/CI_{j_0}^{b,m,z}$, and non-parametrically regressing it on each contextual variable z to determine its marginal effect on the equity composite indicators. This method is outlined in [80]. The smoothed regression line's slope provides a graphic representation of the environmental component z's marginal effect on the frontier [74,76]. An unfavorable influence of z would be indicated by a declining tendency for the ratios as a function of z (the z factor is an undesirable characteristic as higher values of z hidden education systems to reach higher levels of equity). Thus, the education system may reach a lower level of equity performance the higher the z. This suggests that the omission of this undesirable characteristics in the analysis would be more detrimental for the education systems with greater levels of z. Similar to this, a positive slope denotes a positive association: the educational system can attain greater equity the larger the value of z. Lastly, the lack of an effect is shown by a plane line. As a non-parametric regression is used to smooth the line, multiple effects are also possible.

4. Equity performance of the OECD education systems

In this section we present the results for the estimated CI for each dimension (inclusion, segregation and equality of opportunity), and the global Equity Composite Indicator (ECI hereafter). We have estimated six models, three of them using the unconditional Directional Distance Benefit-of-the-Doubt (DD-BoD) model as presented in Section 3 and then we replicate the analysis using the conditional version of the DD-BoD.[12] We will first discuss the results of the unconditional

[12] All models were estimated in the robust version (order-m) and imposing weight restrictions as explained in the previous section.

Table 4
Descriptive statistics for CI for each dimension and ECI — unconditional DD-BoD.

	CI_inclusion	CI_segregation	CI_EOp	ECI
Average	0.953	0.848	0.787	0.862
St. Dev.	0.053	0.095	0.116	0.069
Min	0.727	0.607	0.598	0.728
Q1	0.944	0.806	0.705	0.814
Q2	0.964	0.847	0.768	0.861
Q3	0.982	0.909	0.857	0.912
Max	1.030	1.113	1.118	1.041

Table 5
Correlations between CI for each dimension and ECI — unconditional DD-BoD.

	CI_inclusion	CI_segregation	CI_EOp	ECI
CI_inclusion	1.000	–	–	–
CI_segregation	0.517	1.000	–	–
CI_Eop	−0.014	0.545	1.000	–
ECI	0.488	0.902	0.812	1.000

DD-BoD specification and then we compare them with the results obtained when we take into account the country-specific contextual variables. It is important to start with the unconditional results since they can be compared with the existing literature focused on cross-country performance comparisons. Most importantly, the unconditional measures capture the absolute distance between the least and the most equitable educational system, highlighting the systems most in need of intervention [81]. Second, the comparison between the conditional and unconditional results permits to appraise the implications of not accounting for the heterogeneity across education systems in international benchmarking. To this extent, conditional measures help identify peers with similar contexts, allowing for more tailored interventions and a more accessible, feasible path to reducing inequity.

Table 4 presents the main descriptive statistics for the composite indicators associated to each dimension and the global ECI for the OECD education systems included in the analysis. Higher values of the CI imply a better performance. The potential improvement can be determined by $(1/CI - 1)^{*}100$ percent. Thus, on average, OECD educational systems could improve their performance in equity by 16%.

When we look into the CI for each dimension, we observe that the major room for improvements is in terms of equality of opportunity (EOp hereafter) followed by segregation. On average, OECD education systems could improve the level of EOp in education by 27% and in terms of segregation by 18%. In addition, the variability between education systems is greater in these two dimensions, where the worst performing educational system could improve up to 67% the EOp and up to 65% the segregation. In contrast, with regard to inclusion, the assessed education systems are more homogeneous and on average could improve at most 5%. This result is mainly driven by the relatively good performance in terms of enrollment in educational systems. In 45 out of the 60 education systems analyzed, enrollment rates are at or exceed 95%.

As we have discussed, equity is a multidimensional concept, and education systems perform differently across each dimension. Some systems exhibit balanced strong performance across all dimensions, while others demonstrate contrasting behaviors depending on the dimension considered. Table 5 reports the correlation between the composite indicators estimated for each dimension and the global ECI. The correlation between dimensions allows us to determine whether they are complementary (positively correlated), substitutive (negatively correlated), or unrelated. The results show that segregation and inclusion are complementary dimensions within the sample (significantly positive correlation), while educational opportunity (EOp) and inclusion are not (the correlation is almost zero).

When looking at the ECI, although all dimensions have the same weight (we took the arithmetic average), global equity is more closely related with the segregation and EOp than with the inclusion dimension (although it is significantly positive correlated with the three CIs). This result can be explained by the greater heterogeneity in terms of segregation or EOp across education systems than in terms of inclusion (driven by the smaller variance in terms of enrollment).

Behind the average behaviors commented, we find considerable differences between countries and regions. Table 6 reports the CI score and the ranking for the ECI and each dimension for all the education systems included in the sample, ordered by the most to the least equitable in global terms (ECI ranking).

According to the global ECI results (unconditional DD-BoD), the most equitable education systems are the majority of the Canadian regions (except Quebec, Alberta and Saskatchewan), Norway, Estonia, and Cantabria and Galicia Spanish regions. These findings are consistent with the literature about cross-country performance comparisons, where the Nordic countries, Canada and Estonia usually appear to be the more equitable systems in terms of inclusion and fairness [34,36]. In the case of the Nordic countries, for instance Norway or Iceland, this can be attributed to education policies that ensure equal access, robust public funding, and a strong focus on social inclusion. On the contrary, the most inequitable educational systems are the Latin American countries (Colombia, Mexico, Chile), Hungary, Slovak Republic, Turkey, Israel, but also some Central European countries as Luxembourg, Germany or Belgium. The poor performance of the Latin-American countries (LAC hereafter) is mainly explained by unfavorable results in the segregation dimension. This is due to high economic inequality and the dual structure of the education system (the coexistence of an underfunded public system and an elitist private system), which perpetuates patterns of social exclusion, with schools tending to group students according to their socio-economic background. In contrast, the poor performance of the Central European countries is mostly driven by the equality of opportunity dimension, result which is in line with previous studies who found that these countries are the most unequal in terms of educational opportunities [52,82]. It is interesting to note that when we move to the equality of opportunity dimension, some of the worst performer countries (Colombia, Mexico and Turkey) notably improve their performance, which is not observed for the inclusion and segregation dimensions.

It is worth to highlight the fact that most of the regional education systems (particularly the Canadian), outperform the national educational systems in terms of equity (ECI). In fact, eight out of the ten best performers are regional systems. This success can be attributed to decentralized management and policies specifically tailored to local needs. For example, in the Canadian provinces of New Brunswick and Newfoundland and Labrador, various strategies have been implemented to mitigate school segregation. These strategies primarily focus on the equitable allocation of educational resources and include targeted measures aimed at improving the quality of education in rural areas. When looking at the dimensions, this comparative advantage is mainly led by their well-performance in regards of equality of opportunities and diminishes when we move to the inclusion CI. Another revealing finding is the presence of great divergences in performance among the regional educational systems within the same country, particularly in Spain. While half of the Spanish regional education systems rank among the top 20 in terms of global equity – such as Cantabria and Galicia, which are positioned among the most equitable regions – others, such as Madrid and Asturias, show significantly poorer performance. In the regions of Cantabria and Galicia, the predominantly rural population structure has led to education policies designed to ensure equitable access to schooling in geographically dispersed areas. These policies are characterized by lower student-teacher ratios and a focus on personalized attention, which have contributed to greater equity in educational outcomes. By contrast, the scenario in the region of Madrid is markedly different. While average academic performance in this region is relatively high, there is significant income polarization, with pronounced concentrations of both wealth and poverty.

Table 6
Scores and rankings of CI for each dimension and global equity for OECD countries and regions — unconditional DD-BoD.

	CI score				Ranking	Rank diff (respect ECI)[a]		
	CI_inclusion	CI_segregation	CI_EOp	ECI	ECI	CI_inclusion	CI_segregation	CI_EOp
Canada: New Brunswick	0.9534	1.1129	1.0564	1.0409	1	−39	0	−1
Canada: Newfoundland and Labrador	0.9689	0.9480	1.1181	1.0117	2	−24	−5	1
Canada: Nova Scotia	0.9479	1.0556	0.9193	0.9743	3	−41	1	−6
Canada: British Columbia	1.0005	0.9540	0.9532	0.9692	4	1	−2	−2
Norway	0.9883	0.9831	0.8832	0.9515	5	−5	2	−7
Canada: Ontario	0.9917	0.9252	0.9166	0.9445	6	−1	−5	−4
Canada: Manitoba	0.8958	0.9046	1.0178	0.9394	7	−48	−10	4
Spain: Cantabria	0.9895	0.9791	0.8490	0.9392	8	0	4	−9
Estonia	1.0296	0.8407	0.9413	0.9372	9	8	−23	2
Spain: Galicia	0.9659	0.9002	0.9216	0.9293	10	−19	−8	2
Iceland	0.9642	0.9359	0.8776	0.9259	11	−19	2	−2
Spain: Comunidad Valenciana	0.9587	0.8466	0.9632	0.9228	12	−24	−19	7
Spain: Castile and Leon	0.9889	0.9266	0.8409	0.9188	13	4	3	−7
Spain: Canary Islands	0.9259	0.8548	0.9645	0.9150	14	−37	−15	10
Spain: La Rioja	0.9707	0.9233	0.8470	0.9137	15	−7	2	−3
Spain: Basque Country	0.9831	0.8629	0.8899	0.9120	16	1	−12	5
Canada: Saskatchewan	0.9283	0.9642	0.8308	0.9078	17	−33	12	−4
Spain: Castile-La Mancha	0.9545	0.8795	0.8749	0.9030	18	−20	−5	4
Spain: Balearic Islands	0.9481	0.8846	0.8695	0.9008	19	−24	−2	4
Finland	0.9931	0.9369	0.7644	0.8981	20	14	12	−12
Spain: Aragon	0.9616	0.9072	0.8138	0.8942	21	−13	5	−2
Spain: Navarre	0.9518	0.8861	0.8159	0.8846	22	−20	2	0
Canada: Alberta	0.9817	0.9236	0.7461	0.8838	23	6	11	−14
Sweden	0.9860	0.9152	0.7313	0.8775	24	11	9	−15
Latvia	0.9687	0.8096	0.8410	0.8731	25	−2	−19	6
Canada: Quebec	0.9595	0.8630	0.7943	0.8723	26	−9	−1	2
Ireland	1.0028	0.8887	0.7194	0.8703	27	25	8	−14
Denmark	0.9858	0.9155	0.7070	0.8694	28	14	14	−17
Spain: Extremadura	0.9404	0.8749	0.7869	0.8674	29	−20	5	2
Korea	1.0003	0.8404	0.7554	0.8654	30	26	−3	−4
United Kingdom	0.9869	0.8130	0.7694	0.8564	31	19	−11	1
Japan	0.9743	0.8188	0.7728	0.8553	32	12	−6	3
Spain: Andalusia	0.9641	0.8474	0.7510	0.8541	33	2	3	−3
Spain: Catalonia	0.9823	0.8168	0.7613	0.8534	34	18	−6	1
Spain: Murcia	0.9570	0.8727	0.7151	0.8483	35	−2	9	−7
Australia	0.9789	0.7980	0.7663	0.8477	36	18	−11	5
Netherlands	0.9632	0.8304	0.7348	0.8428	37	5	2	−1
Greece	0.9444	0.8304	0.7515	0.8421	38	−7	4	3
New Zealand	0.9669	0.8801	0.6757	0.8409	39	11	17	−12
Slovenia	0.9943	0.7998	0.7121	0.8354	40	35	−6	−3
Switzerland	0.9525	0.8737	0.6680	0.8314	41	0	16	−12
Italy	0.8738	0.8283	0.7776	0.8266	42	−15	5	14
Spain: Asturias	0.9691	0.8170	0.6728	0.8196	43	18	4	−9
Poland	0.9426	0.8293	0.6824	0.8181	44	−3	8	−5
United States	0.9740	0.7875	0.6854	0.8156	45	24	−3	−3
Lithuania	0.9434	0.7844	0.7008	0.8095	46	0	−3	0
Portugal	0.9703	0.8102	0.6322	0.8042	47	24	4	−8
Spain: Madrid	0.9703	0.7280	0.7098	0.8027	48	24	−6	4
France	0.9537	0.8152	0.6267	0.7986	49	10	8	−8
Belgium	0.9629	0.8083	0.6160	0.7957	50	17	5	−8
Germany	0.9881	0.7836	0.6116	0.7944	51	40	1	−8
Czech Republic	0.9759	0.7613	0.6312	0.7895	52	33	0	−4
Israel	0.9110	0.7590	0.6893	0.7865	53	−1	0	6
Turkey	0.8410	0.7145	0.7871	0.7809	54	−4	−1	28
Luxembourg	0.9213	0.7657	0.6341	0.7737	55	2	4	1
Slovak Republic	0.9410	0.6681	0.6816	0.7636	56	8	−1	6
Colombia	0.7267	0.6342	0.8524	0.7378	57	−3	−2	41
Chile	0.8757	0.6067	0.7296	0.7373	58	2	−2	18
Hungary	0.9255	0.6755	0.5981	0.7330	59	7	3	−1
Mexico	0.7372	0.6550	0.7908	0.7276	60	1	2	35

[a] Note: (a) Rank diff is the difference between the rank position by ECI and by the CI for each dimension. Positive values indicates an upgrade in the ranking and the negative values a downgrade regarding the ranking position by ECI.

This has led to the coexistence of elite schools and under-resourced ones, thereby worsening school segregation. The uneven performance regarding the global equity between regions is also observed across the three dimensions, but particularly in regards of segregation and educational equality of opportunity. In cross-country comparisons, usually Canada and Spain are well positioned in the international ranking based on alternative indicators of inclusion or equality of opportunities in education [34,36,83]. However, we can remark that behind the national average there exist great differences. These results are in line with [24,84,85] who pointed out these great differences regarding educational equity across Spanish regions using data from PISA 2015, PISA 2018 and 2022, respectively. Their findings reinforce the importance of including regional educational systems in the assessment instead of the national system as a whole when the educational competences are decentralized. For these countries, the evidence found underlines the

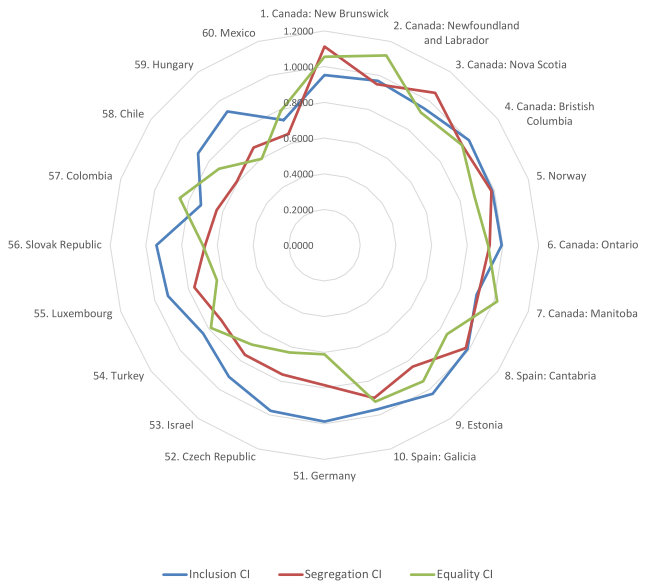

Fig. 2. Equity performance of the Top 10/Bottom 10 OECD equitable educational systems — unconditional DD-BoD.

need for regional education policies to adopt differentiated approaches suited to the unique characteristics of their specific contexts.

In Fig. 2 we present a closer look to the top (bottom) 10 more (less) equitable education systems in OECD. We can observe that some regions are relatively well positioned in terms of one indicator, but very badly in another one, reinforcing the idea that the three dimensions are complementary with each other. This type of analysis could be informative for policy makers in terms of the design of focused policies and interventions. For example, the poor performance in terms of global equity of the LAC is mainly driven by a very poor performance in terms of segregation. In these countries, the high level of school segregation is related with both the concentration of disadvantaged and the concentration of advantaged students. This is consistent with previous literature highlighting that school segregation is particularly severe in Latin America, which is the most segregated region in the world [86,87]. On the contrary, the top equitable education systems show a quite balanced good performance among the three dimensions.

We now incorporate into the analysis the contextual socioeconomic factors of each education system to account for their heterogeneity. We consider three different variables: (i) the Gini index; (ii) the percentage of population with tertiary education; (iii) the unemployment rate. As we have discussed above, all of these variables are out of the control of the educational authorities, but they operate as external factors that could hint the ability of educational systems to be more equitable. Table 7 summarizes the results obtained from the conditional DD-BoD models. As expected, once we account for the heterogeneous conditions across education systems their performance in terms of equity improves compared with the unconditional approach (i.e. we are restricting the reference set to only those education systems with similar conditions). The global ECI raises from 0.862 to 0.907 on average for the OECD education systems, and also the disparity between them is reduced when accounting for the differences in contextual factors. When we look at the CI for the three dimensions behind the ECI, we remark that the improvement in equity performance is mainly driven by the improvements in performance in terms of segregation and equality of opportunities.

Table 8 provides the correlations between the ECI and the CI for each dimension under the conditional specification as well as against the composite indicators obtained under the unconditional approaches. Again, while inclusion seem to be complementary to the rest of the dimensions (the correlation is zero or negative and significant), EOp and segregation are complementary dimensions (significantly positive correlated). Indeed, equality of opportunities and segregation are the most important drivers in terms of global equity (ECI). Conversely, the correlation between the inclusion CI and ECI is close to zero, probably driven by the low variability in terms of inclusion (almost all countries are well-performing). We can observe that when we account for the contextual variables, these factors show a greater effect in terms of segregation and the global ECI, where correlations are lower than for equality of opportunities or inclusion.

Table 7
Descriptive statistics for the CI for each dimension and ECI — conditional DD-BoD.

	CI^c_inclusion	CI^c_segregation	CI^c_EOp	ECI^c
Average	0.967	0.910	0.844	0.907
St. Dev.	0.034	0.070	0.114	0.053
Min	0.830	0.760	0.635	0.794
Q1	0.954	0.856	0.773	0.866
Q2	0.977	0.911	0.814	0.908
Q3	0.991	0.977	0.966	0.949
Max	1.000	1.000	1.000	0.998

Table 8
Correlations between CI for each dimension and ECI — conditional DD-BoD.

	CI^c_inclusion	CI^c_segregation	CI^c_EOp	ECI^c
Conditional				
CI^c_inclusion	1.000	–	–	–
CI^c_segregation	−0.062	1.000	–	–
CI^c_Eop	−0.211	0.530	1.000	–
ECI^c	0.036	0.801	0.900	1.000

Fig. 3 represents the ECI for each education systems under the unconditional and conditional DD-BoD models. We can observe that the improvements across countries are highly heterogeneous. In general, the least developed countries -with the lowest levels of ECI (unconditional) and poor socioeconomic factors (i.e. more income inequality, less percentage of population with tertiary education and higher unemployment rates)- are those who suffer the most (in terms of ranking and scores) when contextual variables are omitted in the analysis. The improvement in more developed countries such as Italy or the United States is striking. In the former case, the improvement responds to the extremely high rate of unemployment, while in the latter case, it is driven by the high levels of income inequality. In both countries, the improvements are driven by an improvement in terms of segregation and specially, in terms of EOp (around 20 pp).

Table 9 reports the ECI and the CI for the three dimensions and the respective rankings under the conditional approach. There are some remarkable findings. First, the majority of the most equitable education systems continue to be in the top of the ranking after controlling for the context with a balanced well-performance in all dimensions. Second, regarding the worst performers, we find two different groups of countries. The LAC notably improve their performance in ECI terms when we account for their poor socioeconomic context and climb up several positions, mostly driven by the improvement in segregation and EOp. In this context, improving the inclusion dimension is presented as a key step toward enhancing educational equity. On the other side, the Central European countries which were the most inequitable under the unconditional specification (Luxembourg, Germany and Belgium) remain at the bottom of the ranking once we account for the contextual factors due to a poor performance in terms of EOp. In these countries, where inequality of opportunities is the main challenge, it is essential to prioritize support programs for students from disadvantaged backgrounds, such as personalized tutoring, increased funding for public schools, and interventions designed to improve teaching quality.

As a by-product of the optimization problem, the BoD model identifies the best practices that the under-performing educational systems should look at to improve their performance. To this extent, the conditional approach helps finding a set of peers with more comparable background characteristics and measuring the room for improvement

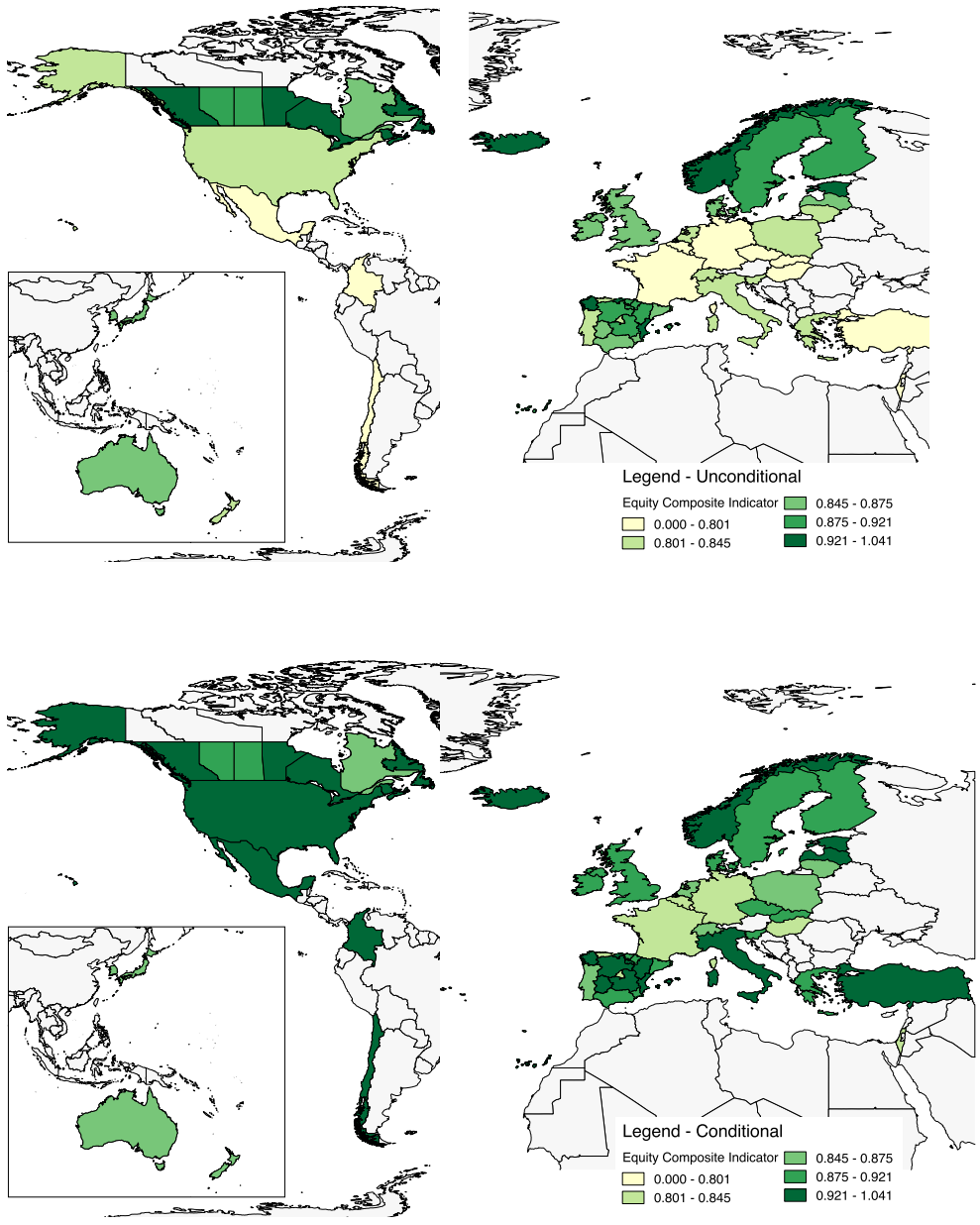

Fig. 3. ECI for OECD educational systems under the unconditional and conditional DD-BoD models.

accounting for a potentially unfavorable context. In this regard, the reference peers significantly change for the LAC and Central European countries when accounting for the context.

Under the unconditional model, the peers were the same for both groups. For the inclusion dimension, Estonia, Canada–British Columbia, Korea as well as Ireland emerge as the most recurrent best practices. For the school segregation, Canada–New Brunswick, Canada–Nova Scotia and Norway result the peers, while for the equality of opportunities dimension we find Canada–Newfoundland and Labrador, Canada–New Brunswick, Canada – Manitoba, Spain–Canary Islands, Spain–Comunidad Valenciana, Canada–British Columbia and Estonia. After accounting for the context, the new peers are countries with similar socioeconomic conditions. For example, for the inclusion dimension when we account for the context, the reference peers only change for the LAC becoming Chile the common reference system. This can be attributed to Chilean policies designed to collectively reduce barriers to education access, improve instructional quality, and ensure students achieve essential competency levels. Regarding the segregation dimension, the peers change for all inequitable systems. Turkey, Chile and Mexico appear as the new peers for the LAC systems, while Norway remains as a common reference peer for the Central European systems. Norway's education system is predominantly public and of high quality, regardless of the location of schools. Due to the country's low levels of residential segregation, students from diverse socioeconomic backgrounds are distributed equitably, effectively preventing school segregation, even with a school assignment system primarily based on place of residence. Consequently, Norway ranks among the countries with lower school segregation. Finally, in terms of the EOp dimension, Colombia becomes the common reference peer for the LAC and Estonia and Latvia for the Central European countries. For instance, in Estonia, a core element of the education system is the support provided to disadvantaged students through targeted measures, such as scholarships and grants for low-income families (access to educational materials, extracurricular activities, free school meals, and free school transport). Additionally, personalized educational plans for students facing academic challenges, including tutoring and remedial

Table 9
Scores and rankings of CI for each dimension and ECI for OECD countries and regions — conditional DD-BoD.

	CI score				Ranking	Rank diff (respect ECI[c])[a]		
	CI_inclusion	CI_segregation	CI_EOp	ECI	ECI	CI_inclusion	CI_segregation	CI_EOp
Canada: Newfoundland and Labrador	0.9983	0.9961	1.0000	0.9981	1	−7	−8	−2
Spain: Castile-La Mancha	0.9947	0.9912	0.9998	0.9952	2	−10	−12	−6
Spain: Canary Islands	0.9682	0.9996	1.0000	0.9892	3	−33	−1	1
Canada: New Brunswick	0.9536	1.0000	1.0000	0.9845	4	−42	2	3
Iceland	0.9646	0.9927	0.9892	0.9821	5	−34	−8	−7
Norway	0.9882	0.9938	0.9592	0.9804	6	−12	−5	−11
Turkey	0.9407	0.9970	1.0000	0.9792	7	−45	0	0
Spain: Balearic Islands	0.9578	0.9969	0.9652	0.9733	8	−35	0	−8
Canada: Ontario	0.9994	0.9264	0.9681	0.9646	9	3	−17	−6
Canada: British Columbia	1.0000	0.9438	0.9422	0.9620	10	9	−13	−9
Spain: Comunidad Valenciana	0.9700	0.9096	0.9992	0.9596	11	−23	−20	2
Spain: Galicia	0.9765	0.9668	0.9275	0.9569	12	−19	−6	−8
Canada: Nova Scotia	0.9479	0.9957	0.9178	0.9538	13	−36	3	−8
Estonia	1.0000	0.8573	1.0000	0.9524	14	12	−30	8
Italy	0.8998	0.9677	0.9895	0.9523	15	−42	−2	4
Mexico	0.8592	0.9996	0.9830	0.9472	16	−43	13	2
Latvia	0.9746	0.8584	0.9958	0.9430	17	−15	−24	7
Spain: Extremadura	0.9793	1.0000	0.8471	0.9421	18	−8	17	−8
Spain: La Rioja	0.9785	0.9971	0.8479	0.9412	19	−10	13	−6
Spain: Castile and Leon	0.9998	0.9938	0.8255	0.9397	20	15	8	−8
Colombia	0.8296	0.9872	1.0000	0.9389	21	−39	6	17
Canada: Saskatchewan	0.9280	0.9652	0.9164	0.9366	22	−32	3	0
Spain: Cantabria	0.9990	0.9987	0.7987	0.9321	23	16	18	−11
Canada: Manitoba	0.8954	0.8972	1.0000	0.9308	24	−34	−9	19
Chile	0.9951	0.8411	0.9530	0.9297	25	14	−25	7
Spain: Aragon	0.9680	0.9731	0.8436	0.9283	26	−11	10	−1
United States	0.9881	0.9124	0.8815	0.9273	27	8	−3	4
Slovak Republic	0.9462	0.8220	0.9832	0.9171	28	−22	−25	15
Spain: Andalusia	1.0000	0.9623	0.7885	0.9169	29	26	8	−10
Canada: Alberta	0.9910	0.9252	0.8131	0.9098	30	14	3	−1
Spain: Murcia	0.9688	0.9641	0.7879	0.9070	31	−4	11	−10
Finland	0.9928	0.9345	0.7920	0.9064	32	19	7	−5
Spain: Basque Country	0.9875	0.8564	0.8620	0.9020	33	13	−12	9
Greece	0.9781	0.9392	0.7744	0.8972	34	4	10	−11
Czech Republic	0.9823	0.9010	0.7967	0.8933	35	11	3	−1
Denmark	0.9862	0.9488	0.7365	0.8905	36	13	14	−14
Sweden	0.9863	0.9201	0.7541	0.8868	37	15	9	−10
United Kingdom	0.9868	0.8527	0.8141	0.8845	38	17	−9	8
Slovenia	0.9974	0.8329	0.8224	0.8842	39	30	−12	10
Spain: Navarre	0.9544	0.8803	0.8036	0.8794	40	−5	2	7
Ireland	0.9967	0.8825	0.7531	0.8774	41	31	4	−7
Spain: Catalonia	0.9922	0.8678	0.7701	0.8767	42	28	3	−4
Korea	0.9999	0.8438	0.7807	0.8748	43	39	−6	−1
Canada: Quebec	0.9619	0.8564	0.7969	0.8717	44	2	−2	9
New Zealand	0.9672	0.9140	0.7187	0.8667	45	7	16	−6
Netherlands	0.9638	0.8454	0.7874	0.8655	46	6	−2	4
Japan	0.9739	0.8295	0.7864	0.8633	47	14	−5	4
Portugal	0.9920	0.8955	0.6971	0.8616	48	33	14	−5
Australia	0.9785	0.8083	0.7885	0.8585	49	21	−7	11
Poland	0.9432	0.8919	0.7393	0.8582	50	−1	14	1
Lithuania	0.9487	0.8166	0.7883	0.8512	51	3	−4	11
Switzerland	0.9522	0.8944	0.6907	0.8458	52	5	17	−2
Israel	0.9182	0.8051	0.8042	0.8425	53	−3	−4	21
Germany	0.9906	0.8583	0.6631	0.8373	54	37	11	−4
Spain: Asturias	0.9790	0.8585	0.6641	0.8339	55	28	15	−2
France	0.9552	0.8584	0.6585	0.8240	56	12	14	−3
Spain: Madrid	0.9816	0.7597	0.7097	0.8170	57	32	−3	5
Belgium	0.9635	0.8187	0.6350	0.8057	58	17	4	−2
Hungary	0.9332	0.7801	0.6899	0.8010	59	6	0	4
Luxembourg	0.9215	0.7931	0.6663	0.7936	60	5	2	4

[a] Note: (a) Rank diff is the difference between the rank position by ECI and by the CI for each dimension. Positive values indicates an upgrade in the ranking and the negative values a downgrade regarding the ranking position by ECI.

classes, are designed to help them achieve their full potential. The analysis of the peers offers valuable insights for identifying practical and effective policies and practices to promote more equitable systems.

Finally, we can shed some light on the role of contextual factors on educational equity by analyzing the non-parametric partial regression plots (Fig. 4). In the reading of these plots, negative (positive) slopes denote a negative (positive) relationship with the educational systems' ECI scores. The Gini Index which captures income inequality seems to be negatively correlated with educational equity, particularly for high levels of income inequality which means that for these countries or regions is more difficult to achieve an equitable education. For instance, in countries like Mexico, Chile, and Colombia, high-income inequality deepens school segregation. Students from wealthier families attend quality private schools, while those from lower-income families are concentrated in underfunded public schools. This dynamic reinforces inter-generational cycles of educational inequity and hinders social mobility. This finding is in line with previous evidence where

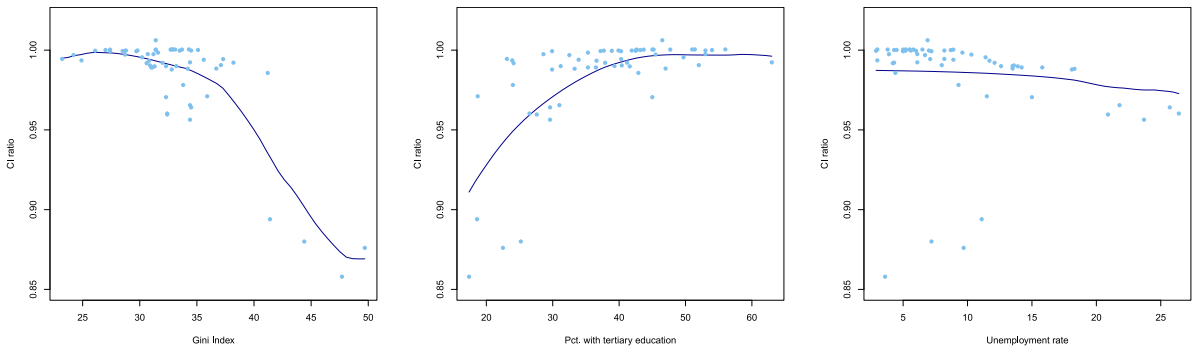

Fig. 4. Non-parametric partial regression plots for the contextual variables.

income inequality is correlated with significant disparities in educational achievement and in turn in lower social mobility [19,60,88]. Second, the percentage of the population between 25–64 years with tertiary levels of education positively correlates with equity, but only for lower values of this variable, confirming some of the findings from some previous studies [89]. This indicates that in countries where the proportion of the population with tertiary education is low, educational gaps tend to be more pronounced. This is likely due to families' limited ability to support their children's learning and the absence of positive educational role models within their communities. Differences in educational levels play a more remarked role in countries where also other differences in income and socioeconomic characteristics are in place, exacerbating the level of educational equity. Finally, in terms of unemployment the association with equity is not very clear, but there is a slight unfavorable effect for high rates, which means that for these education systems is more difficult to promote equity. Italy, for example, shows a significant improvement in terms of the equality of opportunity CI when contextual factors are taken into account. This highlights how high unemployment in the country adversely affects the education system's capacity to ensure a level playing field. In these countries, it seems predominant the "discouraged student effect" [62]: the students of these countries are on average more in financial need and from more disadvantaged socioeconomic backgrounds, hence the opportunity costs of staying in school is more pronounced.

The analysis of contextual factors draws attention to the importance of adopting cross-sectoral approaches to address educational equity. While education policies are crucial for improving equity in education, their effectiveness largely depends on their interaction with economic, social, and labor market policies.

5. Conclusions

This research provides a comprehensive and fair assessment of the degree of global equity of OECD educational systems, based on a synthetic measure. In particular, we construct an Equity Composite Indicator (ECI) using different extensions of the Benefit of the Doubt (BoD) model. This composite indicator enables to compare the performance of the OECD educational systems in terms of equity based on a single criterion, considering the multiple dimensions of equity and respecting the different priorities and particularities of the educational systems.

Our findings support the hypothesis about the need of considering all dimensions (inclusion, segregation and equality of opportunities) simultaneously to compare the performance across education systems. Second, segregation and equality of opportunities show the major room for improvement, particularly for the most inequitable countries. In addition, our findings stress the importance of including in the international comparison the regional education systems when they are the responsible of education policies and resources, since including national systems could hide divergent behaviors across regions. Heterogeneity between regions could be even greater than between countries.

The results provide more specific insights, identifying clear patterns of educational equity across different education systems. Leading the field in terms of educational equity are most regions in Canada, as well as Norway and Estonia. In contrast, Latin American countries such as Mexico, Colombia, and Chile, along with several Central European nations, including Germany, Luxembourg, and Belgium, exhibit the lowest levels of educational equity.

Regarding the contextual socioeconomic context, we evidence that this is specially relevant for countries operating in the most unfavorable conditions (higher income inequality and unemployment and low percentage of population with tertiary education). Thus, depending on the aim of the cross-country assessment, it could be particularly relevant to take into account these characteristics to conduct a fair comparison. On the contrary, the most equitable education systems remain at the top of the ranking when accounting for social and economic contextual factors. The analysis of contextual factors highlights that educational equity cannot be fully understood or addressed in isolation from the broader socioeconomic conditions in which education systems operate. Policymakers must acknowledge that educational equity is not only an educational objective but also a societal concern, requiring comprehensive and coordinated interventions.

We conclude by pointing out some implications in terms of policy and economic development. Making education systems more equitable is a current challenge not only for less developed countries, but also for wealthy ones. Depending on the level of equity within the education system – which in some countries or regions varies according to the dimension under analysis – each system will determine its priorities and implement the most appropriate and effective policies or measures. For example, the Latin-American countries (LAC) education systems have important room for improvement in terms of inclusion by reducing the early dropout and guaranteeing a minimum level of proficiency for all students. This result holds even after accounting for their more disadvantaged context. Examples of policies suitable for these contexts include interventions aimed at ensuring universal coverage, such as scholarship and grant programs designed to promote enrollment and retention within the education system. Additionally, academic remediation initiatives, such as free tutoring or after-school academic intervention programs for students performing below level 2, could also be effective. Improving the inclusion dimension has important implications in economics terms, since as [3] demonstrate, the economic gains in terms of GDP of increasing the percentage of students that reach the minimum level of skills could be enormous. On the other side, Central European countries should put the effort on improving the equality of opportunities in education in order to be more equitable. In these countries, the impact of students' socioeconomic status on their achievements is still very strong, probably associated to certain policies as the existence of tracking at early ages, school choice and admission criteria or the share of private schooling in the education system. These educational policies can also affect

Table 10
Studies of performance of education systems using BoD composite indicators at the country level including equity indicators.

Study	Countries	Database	Desired indicators	Undesired indicators	Method
Stumbriene, Camanho and Jakaitiene (2020)	29 European countries	Eurostat and OECD	Tertiary education attainment; Early childhood education; Employment rates of recent graduates; Adult participation in learning; PISA top achievers; Upper secondary or tertiary attainment	Early leavers; PISA low achievers in maths, reading and science	DD-BoD with fixed and flexible weights
Dominguez-Gil, C.; Segovia-Gonzalez M.M. & Contreras, I. (2021)	33 OECD countries	PISA 2012 and 2015	PISA scores; Share of top achievers in PISA; Share of students above level 2 in PISA; Percentage of resilients; Percentage of the variance in science not explained by ESCS; Sense of belonging index	Overload of working time	Multiplicative BoD
Stumbrienė, Želvys, Žilinskas & Jakaitienė. (2022)	8 post-socialist and 8 old democracy in EU	TIMSS and PIRLS	Percentage of resilients	Standard deviation in TIMSS and PIRLS scores	DD-BoD with flexible weights
Stumbrienė, Želvys, Žilinskas, Dukynaitė & Jakaitienė. (2022)	26 European countries	PIRLS 2016, TIMSS 2016, PISA 2015, Eurostat, UNESCO	Participation in early education; Percentage of disadvantaged students in PISA who attended 2 or more years of early education; Resilient students PIRLS, TIMSS and PISA; Total net enrollment rate in upper-secondary education; Percentage of 20-24 years-old population with at least upper-secondary; Percentage 20-24 enrolled in tertiary education; Percentage of poorest 25-29 years old with at least 2 years of HE	Standard deviation PIRLS, TIMSS and PISA scores	DD-BoD
Camanho, Stumbriene, Barbosa & Jakaitiene (2023)	31 European countries	Eurostat, PISA 2009–2018	Tertiary educational attainment; Early childhood education and care; Employment rates of recent graduates; Adult participation in learning	Early leavers; PISA low achievers in reading, maths and science	Robust DD-BoD
Segovia-González, M.M. & Contreras, I. (2023)	37 OECD countries	PISA 2018	PISA scores; Share of top achievers in PISA; Share of students above level 2 in PISA; Percentage of resilients; Percentage of the variance in science not explained by ESCS; Several indicators related self-perception with respect to school climate, wellness, teacher's performances, etc.	–	Global Malmquist

the distribution of students across schools, which could explain the poor performance in terms of school segregation in Central European countries. To improve equality of opportunity, scholarships and grants for students from disadvantaged backgrounds — such as free access to educational resources, extracurricular activities, school meals, and transportation — along with interventions targeting schools with a high concentration of students from low socioeconomic backgrounds, such as mentoring and guidance programs, serve as clear examples of effective policies. Additionally, school assignment policies designed to ensure a balanced distribution of students from diverse socioeconomic backgrounds, preventing the concentration of (dis)advantaged students, along with incentive programs for schools in socioeconomically disadvantaged areas, could be effective in reducing school segregation. These programs could include the allocation of additional resources to improve infrastructure, provide teacher training, and support teacher retention. LAC also show poor performance in segregation terms, however, they improve once we account for the socioeconomic context of these countries. This reveals that for these education systems, it could be more demanding trying to compensate the great initial social and economic inequalities at the school. Additional policies, as providing free access to early childhood education, can also play a key role in providing all students the same opportunities and improving educational equity.

Finally, it is important to highlight this research is focused on providing a sound comparative assessment of the educational equity and its dimensions across countries. This means the analysis carried out is descriptive in nature and consequently, results should be interpreted as the first stone to the study of international differences in terms of educational equity. From here, various future lines open up that allow us to delve deeper into this issue, such as studying the evolution over time or identifying which factors could causally explain the heterogeneities found between the different education systems.

CRediT authorship contribution statement

Giovanna D'Inverno: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Methodology, Funding acquisition. **Cristina Polo:** Writing – review & editing, Writing – original draft, Visualization, Software, Methodology. **Gabriela Sicilia:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Rosa Simancas:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Table 11
Individual indicators and contextual variables for the OECD countries and regions.

	Inclusion		Segregation			Equality of opportunities			Contextual variables		
	Below 2	Enroll	ISI	Iso_Adv	Iso_Disadv	R2_read	Ratio by SES	Resilients	Gini	Tertiary edu.	Unempl. rate
Australia	19.5	98.8	75.6	0.20	0.19	9.78	3.19	13.13	33.7	45.2	5.8
Belgium	21.1	97.4	76.1	0.16	0.18	17.47	5.26	8.69	27.4	40.3	7.2
Chile	31.5	90.0	56.3	0.23	0.37	12.75	3.12	10.71	44.4	25.2	7.2
Colombia	49.7	75.4	59.5	0.26	0.31	13.63	2.31	10.84	49.7	22.5	9.7
Czech Republic	20.6	98.7	72.3	0.20	0.25	16.46	4.78	9.42	24.9	23.9	3.0
Denmark	15.9	98.7	85.6	0.14	0.11	9.92	3.91	12.22	28.7	38.9	6.0
Estonia	11.0	98.9	79.5	0.18	0.17	6.16	2.58	17.36	30.4	38.4	5.9
Finland	13.5	98.7	87.5	0.10	0.14	8.92	3.16	12.87	27.4	43.7	8.9
France	20.8	96.4	76.8	0.16	0.18	17.65	5.13	10.10	31.6	35.3	9.6
Germany	20.6	100.0	74.0	0.18	0.20	17.84	5.47	9.39	31.2	28.6	3.9
Greece	30.3	97.4	78.2	0.15	0.18	10.92	3.06	11.93	34.4	31.0	21.8
Hungary	25.1	94.3	63.6	0.22	0.28	19.06	5.99	7.24	30.6	24.1	4.2
Iceland	26.2	98.7	87.3	0.14	0.10	6.42	2.41	13.16	26.1	42.5	2.9
Ireland	11.7	98.7	83.0	0.12	0.13	10.81	3.96	13.04	31.4	46.5	6.9
Israel	31.0	93.8	71.6	0.21	0.18	14.29	3.52	7.45	38.2	41.2	4.3
Italy	23.1	88.3	78.1	0.17	0.17	9.01	2.94	12.57	35.9	18.7	11.5
Japan	16.7	97.7	76.8	0.17	0.14	8.02	2.90	11.66	32.9	51.4	3.0
Korea	15.0	100.0	78.9	0.16	0.14	7.92	3.40	13.06	31.4	47.7	3.8
Latvia	22.3	98.3	77.1	0.22	0.20	7.07	2.50	12.33	35.6	33.9	8.9
Lithuania	24.2	96.0	74.6	0.23	0.20	13.31	3.61	11.30	37.3	40.3	7.1
Luxembourg	29.1	94.6	72.2	0.17	0.22	17.62	4.63	8.04	34.5	39.9	5.6
Mexico	44.5	76.0	61.7	0.27	0.29	14.06	2.62	10.27	47.7	17.4	3.6
Netherlands	24.0	98.1	78.2	0.15	0.18	10.60	3.32	12.11	28.5	37.2	5.0
New Zealand	18.8	97.4	82.4	0.15	0.12	12.65	4.00	10.86	33.5	37.7	5.2
Norway	19.2	99.7	91.4	0.09	0.12	7.27	2.30	12.78	27.0	43.2	4.3
Poland	14.6	93.7	78.3	0.15	0.20	11.48	3.91	10.92	29.7	29.9	5.0
Portugal	20.1	98.0	76.7	0.16	0.22	13.55	4.97	9.93	33.8	24.0	9.3
Slovak Republic	31.3	97.2	63.0	0.26	0.27	17.58	3.65	9.96	23.2	23.1	8.2
Slovenia	17.8	100.0	75.5	0.15	0.22	12.18	3.70	12.11	24.2	32.5	6.7
Sweden	18.3	99.3	85.6	0.12	0.13	10.55	3.15	10.85	28.8	41.9	7.0
Switzerland	23.6	96.9	82.3	0.13	0.18	15.39	3.92	9.77	32.7	42.6	5.0
Turkey	25.9	85.3	67.2	0.16	0.28	11.50	3.26	14.40	41.4	18.6	11.1
United Kingdom	17.2	99.1	76.6	0.14	0.21	9.20	3.27	13.47	35.1	42.7	4.5
United States	19.1	98.2	74.2	0.17	0.19	11.99	3.69	10.43	41.2	42.9	4.4
Canada: Newfoundland and Labrador	15.2	96.7	88.2	0.11	0.11	4.03	2.36	20.50	32.3	45.0	15.0
Canada: Nova Scotia	15.0	94.4	91.9	0.08	0.08	5.91	2.36	14.81	31.4	54.0	8.7
Canada: New Brunswick	21.9	96.6	93.0	0.08	0.07	5.56	1.91	15.51	29.8	53.0	8.2
Canada: Quebec	12.1	94.0	81.0	0.14	0.15	9.48	2.81	12.82	30.7	53.0	6.1
Canada: Ontario	13.2	98.3	85.9	0.11	0.11	4.59	2.72	13.86	34.4	63.0	6.1
Canada: Manitoba	19.6	90.0	84.6	0.15	0.11	4.50	2.27	16.35	32.8	51.0	5.5
Canada: Saskatchewan	16.7	92.9	89.4	0.12	0.09	8.49	4.01	16.00	33.1	45.0	6.5
Canada: Alberta	11.8	96.2	85.7	0.11	0.11	9.09	3.65	13.46	37.1	52.0	8.0
Canada: British Columbia	15.0	100.0	88.2	0.12	0.09	5.71	2.17	12.76	34.3	56.0	5.2
Spain: Andalusia	26.9	98.8	79.9	0.16	0.17	10.25	2.98	11.25	34.5	29.6	25.7
Spain: Aragon	19.8	97.0	84.6	0.10	0.14	9.01	3.10	14.85	30.8	36.6	11.7
Spain: Asturias	17.6	97.3	77.0	0.14	0.21	13.48	4.64	12.05	31.3	41.6	13.9
Spain: Balearic Islands	21.6	96.0	82.5	0.14	0.11	7.91	3.26	16.75	32.3	31.2	12.6
Spain: Canary Islands	23.5	94.0	80.3	0.12	0.19	7.62	2.12	15.19	34.4	29.6	23.7
Spain: Cantabria	19.9	100.0	84.6	0.08	0.15	7.09	3.13	16.21	30.9	40.4	13.6
Spain: Castile and Leon	16.0	99.0	86.3	0.10	0.13	9.60	3.56	16.19	31.1	35.3	14.2
Spain: Castile-La Mancha	22.5	96.9	82.6	0.13	0.16	6.83	2.54	14.56	32.4	27.6	20.9
Spain: Catalonia	20.3	99.3	76.6	0.12	0.20	10.06	3.22	13.00	33.2	39.3	13.5
Spain: Extremadura	26.5	96.2	81.8	0.13	0.13	9.20	2.88	12.82	32.4	26.5	26.4
Spain: Galicia	17.6	97.0	84.0	0.10	0.15	7.41	2.42	15.84	31.0	36.5	15.8
Spain: La Rioja	25.6	99.3	85.2	0.09	0.13	8.28	2.98	15.74	32.0	37.9	12.1
Spain: Madrid	24.1	98.9	68.8	0.17	0.28	10.94	3.87	12.36	36.7	47.0	13.5
Spain: Murcia	22.7	97.2	81.7	0.14	0.13	12.68	4.09	13.05	32.8	29.9	18.1
Spain: Navarre	25.0	97.1	82.9	0.12	0.14	7.28	2.65	12.22	28.7	45.5	10.3
Spain: Basque Country	22.9	100.0	81.0	0.14	0.15	6.64	2.45	14.57	30.2	49.7	11.4
Spain: Comunidad Valenciana	23.9	97.6	79.6	0.12	0.20	7.54	2.14	15.39	34.2	33.3	18.3

Appendix

See Tables 10 and 11.

Data availability

Data will be made available on request.

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