





Article

Quality Education for All: A Fuzzy Set Analysis of Sustainable Development Goal Compliance

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Abstract: The relationship between education and societal development is unquestionable. Education contributes to achieving both societies' and individuals' social and economic goals. Quality education is recognized as one of the Sustainable Development Goals (SDGs), which, jointly with other behaviors and attitudes, could impact the development of societies in other fields like health and well-being, cultural preservation, environmental sustainability, and even peace and stability—all of them also listed as SDGs. However, the capacity, or not, to reach higher levels of compliance—with quality in education (SDG 4) varies from country to country, according to the 2023 Sustainable Development Report results. Thus, the present study aims to identify the sufficient conditions for achieving higher levels of quality education (SDG 4) globally and to analyze how these conditions vary across different world regions. Applying a fuzzy set qualitative comparative analysis and using data from the 2023 Sustainable Development Report, we focus our analysis on four SDG 4 indicators—early education, primary education, lower secondary education, and literacy rate—across 117 countries, in order to assess the conditions for attaining higher levels of quality education. The results reveal there are specific and identifiable conditions that are sufficient for achieving higher levels of quality education on a global scale, with significant regional variations. These insights contribute to understanding the complex dynamics of educational quality and could be used as guidance for policymakers and educators aiming to improve educational outcomes worldwide.

Keywords: sustainable development goals; quality education; development; fuzzy set qualitative comparative analysis; regional analysis



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1. Introduction

The relationship between education and the development of society is absolute and indubitable [1], constituting one of the main factors in achieving the social and economic objectives of societies and individuals [2]. It is therefore extremely important to identify the sufficient conditions for attaining higher levels of quality education (SDG 4) globally and to analyze how these conditions vary across different world regions. Education translates into direct and indirect effects on the production of countries [3], presenting itself as an important factor and determinant of economic well-being [4]. At least three mechanisms have been identified through which education can affect economic growth: (i) education can enhance the human capital inherent to the workforce, with repercussions on increased productivity; (ii) the innovative capacity of the economy and new knowledge, particularly in terms of new technologies, products, and processes; (iii) the diffusion and transmission of

knowledge necessary to understand and better process new information and to successfully apply technologies designed by others [4].

Also, from the individual's point of view, education plays an important role, as the acquisition of knowledge and the development of skills tend to promote social values and make individuals more informed, particularly from an economic perspective (e.g., in terms of financial and technological markets), with potential repercussions on economic development [2]. On the other hand, professionals with higher levels of qualification tend to increase national income directly, as their skills contribute to increased productivity [3,4].

Therefore, investment in qualifying human resources tends to translate not only into economic development but also development at social, cultural, and political levels [1]. A previous study precisely corroborated the impacts of education at a demographic, social, institutional, and economic level, assuming itself as a significant determinant of human capital, innovation, productivity, technological progress, and entrepreneurial activity [2]. Moreover, Zolfaghari [1] has stated that education is the only solution to eradicate underdevelopment in today's industrialized world.

Increased investment in education, boosted by favorable economic conditions, can create an environment conducive to education, translating positively into education development [2]. In fact, improving education and increasing the number of qualified people are effective means for the development of society [1]. Therefore, a possible bidirectional relationship between economic growth and education is defended [2]. Indeed, ignoring differences in teaching quality significantly distorts how educational and economic outcomes are related [4].

It should be noted that, in this alignment, education, in multiple ways, constitutes a critical factor not only for economic development but also, and relatedly, for sustainable development [2]. Different international organizations have come to recognize education as a key factor in human development and social well-being, contributing, among others, to improving health, gender equality, social inclusion, democracy, peace, environmental protection, and reducing poverty [5]. Quality education thus emerges as one of the 17 Sustainable Development Goals (SDGs) integrated into the United Nations (UN) 2030 Agenda for Sustainable Development. It aims to guarantee access to inclusive, quality, and equitable education and promotes lifelong learning opportunities for all [6].

The SDGs, launched in 2015 by the UN in agreement with 195 countries, established Sustainable Development Goals to be achieved by 2030 [6]. Research has highlighted the need for sustainable development for humanity and the importance of achieving the expected goals; otherwise, the risk of an increasingly fragmented world will worsen [7]. The SDGs are an integral part of the engine of economic development and social change in public organizations, institutions, non-governmental organizations, and private companies [8].

Of the 17 SDGs, SDG 4 (i.e., quality education) emerges as one of the most prominent objectives [9] and, in line with the relationship between education and development, has a direct and vital role in understanding the social, economic, and political development situation of any country [10]. It constitutes a response to the challenges facing education worldwide, as it influences the productivity, competitiveness, and innovative capacity of countries. Importantly, SDG 4 not only refers to the acquisition of knowledge but also to skill development that enables the active participation of individuals in society and the ability to make informed decisions and face challenges [5,10].

Even so, complexities, limitations, and contradictions have become evident, with consequent difficulties in achieving the 17 SDGs. In an attempt to ensure that the SDGs are moving in the right direction, it is essential to monitor their progress, assess what has changed since the launch of the SDGs (i.e., evolution since their implementation), detect problems, and define development priorities to be implemented in different contexts [11].

As we approach 2030, the difficulty in achieving what is planned within the stipulated deadline becomes evident. Therefore, since the SDGs are roughly halfway through the deadline set for their implementation in the Agenda 2030, it seems reasonable to assess whether there has been any change in sustainability trends since its launch. It is worth high-

lighting the existence of reports published by the UN that detail the global implementation of the SDGs and analyze specific goals and indicators, considering a diversity of contexts and consequent variations in the applicability of the worldwide indicator system [11]. Monitoring compliance with the SDGs and its “immediate” implication can also be crucial in the medium term. In this sense, the results can fuel the discussion and contribute to thinking about the future sustainability framework or strategy to be implemented until 2030, when the SDGs expire, most likely leaving much work to be done. Therefore, monitoring can be fundamental at the local and global policy levels in defining an approach that is more appropriate and realistic. The UN encourages specific studies by countries, to accurately assess the SDGs’ progress and promote integrated global, national, and regional assessments [11].

The Sustainable Development Report (SDR), published in 2023, translates the assessment of the SDGs based on the most recent data and estimates and highlights some existing gaps. The impacts of the climate crisis, the war in Ukraine, a weak global economy, and the persistent effects of the COVID-19 pandemic have translated into weaknesses and impeded progress towards achieving the SDGs, with particular repercussions on the poorest and the most vulnerable groups. None of the SDGs, including SDG 4, are on track to be achieved by 2030, with progress being weak or insufficient in more than 50% of the SDG targets, and in 30%, there has been stagnation or even a setback [7].

Progress towards quality education was already below expectations before COVID-19, but the pandemic devastated education, causing learning losses in about 80% of the 104 countries assessed [7,12]. Inequalities at the level of SDG 4 are reflected in access to inclusive, quality and equitable education, promoting lifelong learning opportunities for all, with significant variations being recorded, among other dimensions, in the scope of access to education, basic school infrastructure, resources (namely digital), and teaching staff qualification. If additional measures are not taken, achieving the goals will be irreparably compromised [7].

Thus, SDR warns of the urgent need to intensify efforts to ensure that compliance with the SDGs progresses towards ensuring a sustainable future for all [7]. Development contributes to future generations having better access to resources and enjoying longer and healthier lives. In this way, considering the lag of the expected goals, the UN has defined areas that require urgent action, emphasizing the potential for success through strong political will and the use of technology, available techniques, resources, and knowledge [7]. The governments of each country play a fundamental role in promoting sustainable development; however, achieving the SDGs also implies a transformation of society as a whole [7]. Thus, significant changes to policies and practices are necessary [13].

It is also important to highlight that knowledge and learning constitute key success factors for implementing the SDGs [8]. In this sense, quality education emerges as an SDG with the potential to impact others in the short and long term [1,2]. SDG 4 is the cornerstone for achieving all other SDGs, meaning that quality education is one of the most powerful and proven means for sustainable development [5,9,10,14,15]. Ultimately, promoting SDG 4 for all children is perhaps the most important key to achieving long-term sustainable development [7]. Therefore, identifying the parameters to improve education is essential to achieving the SDGs [2].

Despite global efforts, there are still significant disparities in educational quality, which makes it difficult to achieve SDG 4. Furthermore, there is limited understanding of the specific conditions that are sufficient for achieving high-quality education across diverse regions. It is therefore necessary to (i) comprehensively identify the factors and conditions that lead to high-quality education outcomes; (ii) analyze how these conditions differ across several global regions in order to tailor strategies for local contexts; and (iii) obtain data-driven insights to inform policymakers and educators on effective measures to improve educational quality. Consequently, we defined the following research questions: (i) What are the sufficient conditions for achieving higher levels of quality education (SDG 4) globally? (ii) How do these sufficient conditions vary across different world regions?

Aiming to answer these research questions, we formulated two research hypotheses: (i) There are specific, identifiable conditions that are sufficient to achieve higher levels of quality education (SDG 4) on a global scale. (ii) The sufficient conditions for achieving quality education differ significantly between world regions.

This research aims to identify sufficient conditions for the full achievement of SDG 4 and analyze whether sufficient conditions change between major world regions. Our main results reveal that globally, all the conditions [early education (EE), primary education (PE), lower secondary education (SE), and literacy rate (Lit)] are necessary conditions for the achievement of SDG 4; however, Lit is the most prominent, followed by SE, EE, and PE. Considering the sufficient conditions for the achievement of SDG 4, the results reveal that EE and SE emerge as sufficient conditions to such an end, with SE being slightly more influential in the world's achievement of this SDG. However, this study identifies significant disparities regarding the sufficient conditions for achieving SDG 4 when a regional level is considered. For the American and European regions, EE is sufficient for the achievement of SDG 4, while for Africa, EE and EE combined with PE are sufficient conditions for that achievement. The Asia region exhibits a more diversified set of sufficient conditions (EE, SE, and Lit) for achieving SDG 4.

2. Materials and Methods

2.1. Data

The SDR is an annual report that evaluates the progress made each year on the SDGs since their adoption by the 193 UN Member States in 2015. According to [7], from 2015 to 2019, the world made some progress on the SDGs, but this progress is insufficient to achieve them. The outbreak of the COVID-19 pandemic and other crises that spread out simultaneously and after have contributed to a worldwide stall of the SDG progress. The response to the multiple crises was not similar for all countries. The high-income countries seemed to mitigate the impacts of these multiple crises due to automatic stabilizers, emergency expenditures, and recovery plans. However, only limited progress is being made on the environmental and biodiversity goals.

On the other hand, in low-income and lower-middle-income countries, the disruptions caused by these multiple crises have aggravated fiscal space issues, leading to a reversal in progress on several goals and indicators. The SDG Index assesses each country's overall performance on the 17 SDGs, giving equal weight to each SDG goal. Each country's score reveals its position on achieving the SDGs. Its score can be between 0 (i.e., the worst possible outcome) and 100 (i.e., the best possible outcome, the target).

Education is crucial to building the human capital that fuels economic growth. It spurs innovation, provides decent job prospects, reduces extreme poverty levels, and addresses gender and other disparities. The years of compulsory education in the law are not equal between all the world regions, varying from zero years in Oceania, eight in Sub-Saharan Africa, nine years in East and South Africa, 10 in Eastern Europe, Central Asia, Middle East, and North Africa, and finally 11 years in Latin America and the Caribbean and OECD members [7]. According to the 2023 SDR, SDG 4 is one of the SDGs in a stagnant situation, being part of the 67% with limited or no progress [7]. Considering the major world regions, they reveal different patterns in achieving SDG 4. The OECD members are the only ones that are on the pathway to "SDG achievement" with "Moderately Increasing" (meaning the score increases at a rate above 50% of the required growth rate but below the rate needed to achieve the SDG by 2030). On the opposite side, in Oceania and Sub-Saharan Africa, "Major challenges remain," with the former with a "Moderately Increasing" and the latter "Stagnating" (i.e., the score remains stagnant or increases at a rate below 50% of the growth rate needed to achieve the SDG by 2030. It also denotes scores that currently exceed the target but have decreased since 2015). In Small Island Developing States, the Middle East, and North Africa, "Significant challenges remain" but with differences between them. The former displays a "Moderately Increasing" and the latter has a "Decreasing" (meaning a decreasing score, i.e., the country moves in the wrong direction) trend. In East and South

Asia, Eastern Europe and Central Asia, and Latin America and the Caribbean, “Challenges remain” too, with the former having a “Stagnating” and the latter having a “Moderately Increasing” trend [7].

Considering these different achievements and patterns, this study aims to answer the following research questions: (i) What are the sufficient conditions for achieving higher levels of quality education (SDG 4) globally? (ii) How do these sufficient conditions vary across different world regions? Considering the research questions, we formulate the following research hypotheses: (i) There are specific, identifiable conditions that are sufficient to achieve higher levels of quality education (SDG 4) on a global scale. (ii) The sufficient conditions for achieving quality education differ significantly between world regions.

SDG 4 comprises eight indicators, but only four (as described in Table 1) are available for all countries. The other four are only available for OECD countries. Considering the main goals of this research, the four indicators available for all the countries were utilized.

Table 1. The SDG 4 indicators.

Indicator	Description	Acronym
Early education	Participation rate in pre-primary organized learning (percentage of children aged 4 to 6). Participation rate in organized learning one year before the official primary entry age measured by the adjusted net enrollment rate in organized learning.	EE
Primary education	Net primary enrollment rate (%) represents the percentage of children of the official school-age population enrolled in primary education.	PE
Secondary education	Lower secondary completion rate (%) is measured as the gross intake ratio to the last grade of lower secondary education (general and pre-vocational). It is calculated as the number of new entrants in the last grade of lower secondary education, regardless of age, divided by the population at the entrance age for the last grade of lower secondary education.	SE
Literacy rate	Literacy rate corresponds to the percentage of youth aged 15 to 24 who can read and write a short, simple statement about everyday life with understanding.	Lit

Note: This table displays the four indicators that compose SDG 4 and are analyzed in this research. It also includes a description of each indicator and the acronym used in the research.

However, of the 193 UN Member States, not all have data available on these four indicators, leading us to consider 117 countries: 42 from Africa, 21 from America, 31 from Asia, and 23 from Europe (as detailed in Table 2). The year 2022 was considered because it is the year (between the most recent available) with more complete data. The data were retrieved from <https://dashboards.sdgindex.org/explorer>, accessed on 2 February 2024.

Table 2. Countries and regions considered in the analysis.

Region	Country				
Africa	Algeria	Angola	Benin	Botswana	Burkina Faso
	Burundi	Cabo Verde	Cameroon	Central African Republic	Chad
	Comoros	Congo, Rep.	Cote d’Ivoire	Dominican Republic	Egypt, Arab Rep.
	Ethiopia	Gambia, The	Ghana	Guinea	Guyana
	Kuwait	Lesotho	Liberia	Madagascar	Mali
	Mauritius	Morocco	Namibia	Nicaragua	Niger
	Papua New Guinea	Rwanda	Sao Tome and Principe	Senegal	Sierra Leone
	South Africa	South Sudan	Sudan	Tanzania	Togo
	Uganda	Zimbabwe			

Table 2. Cont.

Region	Country				
America	Argentina	Barbados	Belize	Bolivia	Brazil
	Chile	Colombia	Costa Rica	Cuba	Ecuador
	El Salvador	Guatemala	Honduras	Mexico	Panama
	Paraguay	Peru	Suriname	Trinidad and Tobago	Uruguay
	Venezuela, RB				
Asia	Bahrain	Bangladesh	Bhutan	Brunei Darussalam	Cambodia
	India	Indonesia	Iran, Islamic Rep.	Jordan	Kazakhstan
	Korea, Rep.	Kyrgyz Republic	Lao PDR	Malaysia	Maldives
	Mongolia	Myanmar	Nepal	Oman	Philippines
	Qatar	Russian Federation	Saudi Arabia	Singapore	Syrian Arab Republic
	Tajikistan	Thailand	United Arab Emirates	Uzbekistan	Vietnam
Yemen, Rep.					
Europe	Albania	Armenia	Azerbaijan	Belarus	Croatia
	Cyprus	Estonia	Greece	Hungary	Italy
	Latvia	Lithuania	Malta	Moldova	Montenegro
	North Macedonia	Poland	Portugal	Romania	Serbia
	Slovenia	Spain	Turkey		

Note: Turkey is a transcontinental country, with its territory divided between the European and Asian continents. In this study, Turkey was included in the “Europe” region given its integration in European organizations (Turkey is a member of the Council of Europe and the OECD), its association with the EU (Turkey is a candidate country for EU membership and has sought to strengthen political, economic and social ties with European countries), as well as geopolitical criteria (although most of Turkish territory is in Asia, the city of Istanbul, one of the most important areas of the country, is located in Europe).

2.2. Methods

Qualitative comparative analysis (QCA) was introduced in the literature by [16]. Since then, it has been developed (see, for example, [17]), being used not only in social sciences but also in economics and management (see, for example, [18] for a brief literature review in this regard). The QCA method can capture patterns of multiple-conjunctural causation and simplify complex data structures logically and holistically by using Boolean algebra (i.e., QCA has binary data as an input and uses logical operations for the procedure) and Boolean minimization algorithms [16]. The QCA is an asymmetric data analysis method that combines the logic and empirical intensity of qualitative approaches with quantitative methods that deal with large numbers of cases and are more generalizable [16]. The fuzzy set qualitative comparative analysis (fsQCA) is one of the three variations of the QCA, with the other two being crisp-set QCA (csQCA) and multi-value QCA (mvQCA). The former treats variables as dichotomous, and the latter treats them as multi-valued. The fsQCA was developed to overcome some limitations of the csQCA and mvQCA, such as using binary variables. It integrates fuzzy sets and fuzzy logic principles with QCA principles [19], offering a more realistic approach since variables can have all the values within the range 0–1. The fsQCA accounts for individual outcomes (or effects) and the patterns (conditions) that cause the outcomes (see, for example, [20]). It “aims to reveal the minimal (combinations of) conditions bringing about a particular outcome in specific cases” [21] (p.171). The fsQCA, more than conducting a pure cause–effect analysis, can analyze different combinations of conditions in a problem [17]. It is a well-suited method for small- or medium-sized samples, as in our case (see, for example, [21]). This method allows the capture of two types of conditions: the necessary and the sufficient.

In this paper, we aim to identify (not estimate) the sufficient conditions for the full achievement of SDG 4 and analyze if the sufficient conditions change between the major world regions. Thus, the fsQCA seems to be the most suitable method, as it will allow us to identify, from a set of conditions to be analyzed (the four indicators of the SDG 4), which ones are sufficient (as all the four are necessary) for a given outcome and different

world regions. All the conditions are explained in Table 1, and our outcome variable is the achievement of SDG 4. Thus, our model can be summarized as $SDG4 = f(EE, PE, SE, Lit)$, with $f(.)$ meaning a function of.

A necessary condition denotes “that an outcome can be attained only if the attribute in question is present” [22], i.e., it must be present for the outcome to occur. On the other hand, a sufficient condition denotes “that an outcome will always be obtained if the attribute in question is present” [22] (p.1184), i.e., if it can produce a certain outcome by itself. However, the outcome can be a result of other conditions.

The consistency measure of [23] “assesses the degree to which instances of an outcome agree in displaying the causal condition thought to be necessary [23] (p.292). Thus, it measures the necessary conditions by measuring the degree to which each case corresponds to a set-theoretic relation given by a solution, and it is used to analyze the necessary conditions in this study. This measure captures the proportion of cases that are consistent with the outcome and penalizes severe inconsistencies. The coverage “assesses the “relevance” of the causal condition—the degree to which instances of the causal condition are paired with instances of the outcome” [23] (p.292).

The true table algorithm (see [17]) is applied to analyze the sufficient conditions, which groups causal conditions in core and peripheral causes. For sufficient conditions, the consistency level is the measure used [17].

In the fsQCA, data must be calibrated [17]. In this process, it is established by the researcher for each condition and the outcome: (i) the fully in set (the variable should have the value of one); (ii) the fully out of set (the variable should have the value of 0); and (iii) the crossover point (0.5), which means that the observation is neither in nor out of the set. The calibration process aims to rescale conditions in an interval ranging from 0 to 1. The number of fuzzy sets defined can be different between studies. In this study, three sets were considered for each condition and outcome. Data calibration was based on a percentile approach suitable for continuous data [17]. As we applied the percentile approach, the “fully in” was defined by the 95th percentile, the “fully out” as the 5th percentile, and the “neither in nor out” point was defined by the 50th percentile. This criterion was considered for all conditions and the outcome. The fsQCA approach is used to obtain causal configurations from data from specific cases. We used fsQCA 4.1 software for Windows, which was downloaded from <https://sites.socsci.uci.edu/~cragin/fsQCA/software.shtml>, accessed on 5 May 2024 to conduct the analysis. This software was employed exclusively for transforming and calibrating variables, as well as for performing the fuzzy set analysis itself. Additionally, we used standard statistical software (namely, Microsoft Excel® for Microsoft 365 MSO, version 2403 Build 16.0.17425.20236, 32-bit) to preprocess and clean the data, ensuring their suitability for the fsQCA. No further tools or frameworks were required beyond these mentioned.

The fsQCA allows us to obtain three combinations of configurations that are supported by a high number of cases, i.e., three solutions (complex, parsimonious, and intermediate) where the rule “the combination leads to the outcome” is consistent [24]. As the complex solution presents all the possible combinations that result from applying traditional logical operations, it produces many complex solutions, even with configurations with several terms, making them difficult to interpret (even impractical). Thus, the solutions are simplified (based on simplifying assumptions) in the parsimonious and intermediate solutions. The parsimonious solution presents the conditions that cannot be left out from any solution, i.e., the “core conditions” [25]. The intermediate solution, like the parsimonious solution, is part of the complex solution and includes the parsimonious solution, meaning that there are a set of conditions common to both the parsimonious and the intermediate solution, the “core conditions”. The conditions presented in the intermediate solution but not in the parsimonious solution are called “peripheral conditions” [25]. Thus, the “core conditions” can be easily identified by examining the parsimonious solution. It is possible that the parsimonious solution and the intermediate solution are exactly the same. Thus, no elaboration is useful beyond the parsimonious solution in this situation. Furthermore,

by including additional conditions in the solution, we increase the complexity in favor of increased consistency [24].

The overall solution consistency is similar to a correlation, and the overall solution coverage is comparable with the R-square obtained on regression-based methods, describing the extent to which the outcome of interest may be explained by the configurations [26].

For clearer understanding of our research methodology, we have included a flow diagram outlining the key steps involved in our analysis. This diagram (see Figure 1) summarizes the process from data collection to obtaining results.

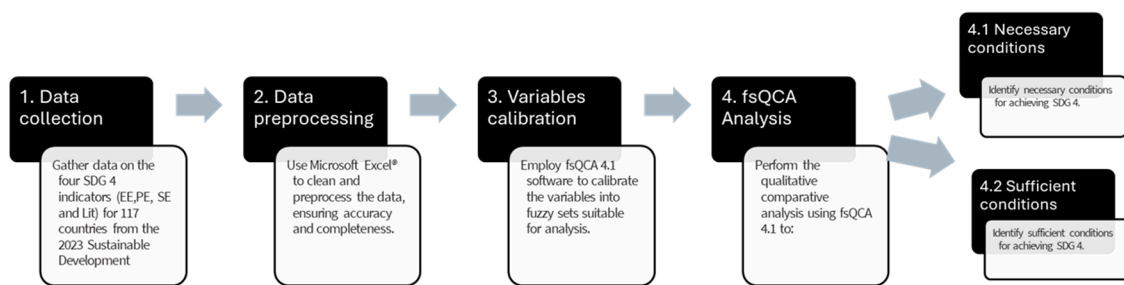


Figure 1. Flow diagram of the research methodology.

3. Results and Discussion

We started our analysis by testing which causal conditions, or their negation, are necessary to achieve SDG 4. We performed this analysis first considering all the countries in the sample (representing the world) and, then, for each world region considered, namely Africa, America, Asia, and Europe. The results are displayed in Table 3.

Table 3. Necessary conditions for the achievement of the SDG 4.

Condition	All Sample		Africa		America		Asia		Europe	
	Con.	Cov.	Con.	Cov.	Con.	Cov.	Con.	Cov.	Con.	Cov.
fsEE	0.8827	0.9045	0.7861	0.6999	0.9364	0.8726	0.8445	0.9743	0.9292	0.9792
~fsEE	0.3922	0.4204	0.8175	0.2283	0.3442	0.7727	0.4124	0.5860	0.2044	0.7427
fsPE	0.8744	0.8065	0.9227	0.5212	0.8583	0.9481	0.9281	0.8153	0.8068	0.9687
~fsPE	0.4038	0.4896	0.7514	0.2562	0.4121	0.6722	0.3014	0.6975	0.3401	0.8694
fsSE	0.8846	0.8718	0.7794	0.7235	0.8004	0.9609	0.9215	0.8356	0.9580	0.9336
~fsSE	0.3818	0.4269	0.7514	0.2562	0.4570	0.6667	0.2953	0.6316	0.1778	0.8978
fsLit	0.9023	0.8254	0.8712	0.6667	0.9205	0.8713	0.8506	0.8135	0.9580	0.8964
~fsLit	0.3976	0.4874	0.9283	0.2733	0.3702	0.8013	0.4184	0.7973	0.1437	0.9247

Notes: (i) “Con.” and “Cov.” correspond to Consistency and Coverage measures, respectively; (ii) fs represents the calibrated variable; (iii) ~ represents the negation of the condition.

Considering the whole sample, the condition corresponding to the percentage of youth (aged 15 to 24) who can read and write a short, simple statement on everyday life with understanding (Lit) exceeds the threshold of 0.90. All the remaining conditions (EE, PE, and SE) have consistency greater than 0.8, which is considered the minimum level of consistency for solutions to be accepted (see, for example, [25]). With the fsQCA method, we can analyze conditions to verify an outcome and negate that outcome. As shown in Table 3, all the negated conditions display consistency below the threshold of 0.8, which is coherent with the literature and according to what was expected.

Considering the world regions, there are two conditions in Africa: the participation rate in pre-primary organized learning (EE) and lower secondary completion rate (SE), with consistency levels of 0.79 and 0.78, respectively. This level of consistency, although slightly less than 0.8, is greater than 0.75 (that is, the minimum threshold recommended by [17,23]). The other two conditions, PE and Lit, reveal consistency above 0.8, again following what was expected. For this world region, the negation of EE and Lit is necessary

for achieving SDG 4. This world region can identify EE and Lit not as priorities since other factors may play a more significant role in the promotion of the achievement of SDG 4. The negation of EE and Lit as necessary conditions may reflect the complexity of interactions between other factors, highlighting the importance of considering various factors in formulating effective educational policies. Regional variations in educational needs and development priorities may also justify negating these conditions. For the America region, all the conditions reveal a level of consistency above 0.8, with EE and Lit being superior to 0.9. In Asia, all the conditions are also necessary because they all display a level of consistency higher than 0.8. For this region, two conditions display a level of consistency higher than 0.9, namely the PE and SE. However, these two conditions are not the same for America. This evidence may reflect the distinct socio-economic and cultural contexts between Asia and America (e.g., in Asia, countries such as China, India, and Japan have highly competitive educational systems, emphasizing standardized exams and preparation for specific careers. In contrast, in America, educational systems vary from models centered on freedom of choice to more holistic approaches), as well as differences in terms of educational infrastructure and attitudes towards education (e.g., in Asia, the emphasis on academic excellence is often high, with pressure on students to succeed in exams. On the other hand, in America, there is a wider range of educational approaches, including greater value on creativity, innovation, and practical learning). For the Europe region, all the conditions reveal a level of consistency above 0.8, with three conditions (EE, SE, and Lit) being superior to 0.9. All these results make sense and are in line with the literature.

In addition to the necessary conditions, the fsQCA method also allows the identification of sufficient conditions for a given outcome, i.e., the conditions which, when verified, will imply that an outcome will always be obtained. The results of those conditions are presented in Table 4, which displays the intermediate and the parsimonious solutions. According to [25], combining the parsimonious and intermediate solutions can offer a more detailed and aggregated view of the findings. Thus, we present both solutions.

Table 4. Sufficient conditions for the achievement of the SDG 4.

		Raw Coverage	Unique Coverage	Consistency
All sample	Intermediate Solution			
	fsEE	0.8827	0.1056	0.9045
	fsSE	0.8846	0.1075	0.8718
	Solution coverage	0.9902		
	Solution consistency	0.8183		
	Parsimonious Solution			
	fsEE	0.8827	0.1056	0.9045
	fsSE	0.8846	0.1075	0.8718
	Solution coverage	0.9902		
	Solution consistency	0.8183		
Africa	Intermediate Solution			
	fsEE	0.7794	0.2184	0.7235
	fsEE*fsPE	0.7256	0.1646	0.8110
	Solution coverage	0.9440		
	Solution consistency	0.6717		
	Parsimonious Solution			
	fsEE	0.7794	0.2184	0.7235
	fsEE*fsPE	0.7256	0.1646	0.8110
	Solution coverage	0.9440		
	Solution consistency	0.6717		

Table 4. Cont.

		Raw Coverage	Unique Coverage	Consistency
America	Intermediate Solution			
	fsEE		0.9364	0.8726
	Solution coverage	0.9364		
	Solution consistency	0.8726		
	Parsimonious Solution			
	fsEE		0.9364	0.8726
Asia	fsEE		0.9281	0.8153
	fsSE		0.9215	0.8356
	fsLit		0.8506	0.8135
	Solution coverage	0.9970		
	Solution consistency	0.7480		
	Parsimonious Solution			
	fsEE		0.9281	0.8153
	fsSE		0.9215	0.8356
	fsLit		0.8506	0.8135
	Solution coverage	0.9970		
	Solution consistency	0.7480		
	Europe	Intermediate Solution		
fsEE*fsPE*fsLit			0.7493	0.9965
fsEE*fsSE*fsLit			0.8638	0.9988
Solution coverage		0.8893		
Solution consistency		0.9958		
Parsimonious Solution				
fsEE			0.9292	0.9792
Solution coverage		0.9292	0.9292	
Solution consistency	0.9792			

Note: “*” means “and” and indicates the simultaneous presence of the conditions identified.

As stated by [24], a subset of the simplifying assumptions used to compute the parsimonious solution is used to obtain the intermediate solution. This subset of simplifying assumptions should be consistent with theoretical and empirical knowledge. Based on previous knowledge, the researcher may choose whether one of the variables should be considered only present, only absent, or both in explaining the outcome. Considering the referred and based on previous knowledge presented in the Section 1, the variables are considered only present.

Considering that the parsimonious solution presents the most important conditions that cannot be left out from any solution [25], and as according to [24], in situations where the intermediate and the parsimonious solutions are exactly the same, no elaboration is useful beyond the parsimonious solution. Thus, our analysis will be conducted based on the parsimonious solution. In our case, except for the European region, the intermediate and parsimonious solutions are the same as those of other world regions and the whole sample. The total coverage refers to the joint importance of all causal paths, and both (the solution consistency and coverage) show that those causal paths cover the greatest part of the outcome.

All the world regions and the whole sample present total coverage above 0.92, meaning that the causal paths indicated cover the biggest part of the outcome (the achievement [27], which, according to [17,28], validates the existence of robustness). Pre-primary education provides a stimulating environment for children’s cognitive, social, and emotional development; it promotes essential skills such as literacy, calculus, and problem-solving [29–31]. On the other hand, successful completion of lower primary education is crucial for continued

education, as it provides a solid foundation for more advanced skills in secondary and higher education [32].

Several studies (see, for example, [33,34]) show that countries with high rates of participation in EE and completion of lower primary education generally have better indicators of human and economic development. The evidence found is in line with the literature, showing that investing in EE quality and ensuring the successful completion of SE are crucial steps to achieving SDG 4 worldwide [7]. Considering that children who are well educated from a young age become informed and active citizens and are more likely to participate in sustainability initiatives and contribute to the development of their communities and that students who complete lower primary education are more likely to be involved in civic and economic activities, strengthening the foundations for sustainable societies [33,34], then investing in EE and ensuring the successful completion of SE not only benefits individual children but also contributes to a more sustainable and equitable future for all humanity [5,9,10,14,15].

We split our sample into four world regions to determine whether sufficient conditions differ between regions. For Africa, the sufficient conditions for the achievement of SDG 4 are the EE (with raw coverage of 0.78) and the EE combined with the PE (with raw coverage of 0.73), meaning that PE (solely) is not a sufficient condition for the achievement of SDG 4. This evidence suggests that investing in quality pre-primary education (EE) and ensuring a smooth transition to primary education (PE) are crucial steps toward achieving SDG 4 in Africa. This last condition is the most important sufficient condition since the unique coverage ranges from 0.16 (to the EE combined with PE) to 0.22 (to the EE). In this case, the consistency of both solutions is also above 0.7, validating the existence of robustness, being the conditions identified as credible and relevant to achieving SDG 4 in Africa. In the case of America, only the sufficient condition EE (with raw and unique coverage of 0.9364) is needed to achieve SDG 4. The consistency of this solution is 0.87, meaning the solution is robust. For Asia, we find three different sufficient conditions for achieving SDG 4: the EE (with raw coverage of 0.93), SE (with raw coverage of 0.92), and Lit (with raw coverage of 0.85). These conditions display unique coverages ranging from 0.01 to 0.05. All the solutions display a consistency that ranges from 0.81 to 0.84, above 0.7, also revealing the robustness of the solution. Considering the European region, as in the case of America, only the EE condition (with raw and unique coverage of 0.9292) is sufficient for achieving SDG 4. This solution's consistency is 0.98, also validating its robustness.

The results reveal that the sufficient conditions for achieving SDG 4 vary between global regions. Worldwide (here represented in the whole sample), EE and SE are the sufficient conditions necessary for achieving SDG 4. Moreover, for some world regions (e.g., America and Europe), the only sufficient condition for attaining the referred SDG is EE. Asia is the world region with more sufficient conditions (EE, SE, and Lit) for the achievement of the studied SDG.

While this study provides significant and relevant insights into the conditions necessary for achieving higher levels of quality education (SDG 4) globally, some limitations can be highlighted. First, the fsQCA approach, while robust, may oversimplify the complex relationships between variables. Secondly, this study focuses on a limited set of indicators for SDG 4 (those with data available for all the countries, as explained in Section 2.1), which may not capture all relevant aspects of educational quality. Future research could address the limitations identified, for example, by expanding the range of indicators to include other aspects of education, such as tertiary educational attainment (% of the population aged 25 to 34) or variation in science performance explained by socio-economic status (%). Moreover, applying other complementary methodologies, such as mixed-method approaches, could yield deeper insights into the causal mechanisms underlying educational outcomes. Another possible future line of research is to perform longitudinal studies that track changes over time, which could also help to understand the dynamics of achieving SDG 4. Finally, future research should explore the underlying reasons for the regional differences found, and investigate the impact of cultural, economic and social factors on

educational quality. This will help in developing more nuanced and effective educational policies and practices globally.

4. Conclusions

The main goals of this study are to analyze the necessary and sufficient conditions to achieve the SGD 4 and identify if they differ across several world regions. The fsQCA approach was applied to identify those conditions, as it does not capture causality but identifies the conditions to reach a designated outcome. Additionally, the fsQCA fits well with reduced samples, which is our case.

Our research delved into identifying the conditions that must be achieved, focusing on four indicators: EE, PE, SE, and Lit. Our analysis revealed significant findings regarding the necessity of these conditions for achieving SDG 4. Globally, Lit emerged as a necessary condition for achieving SDG 4, exceeding the threshold of 0.90, followed by SE, EE, and PE, all displaying consistency levels above 0.8, as expected. This result highlights the relevance of these conditions (indicators) in contributing to the achievement of SDG 4. Furthermore, utilizing the fsQCA method allowed us to explore both causal conditions and their negations, shedding light on the importance of considering alternate scenarios. Globally, the negated conditions displayed consistency levels below the threshold of 0.8, aligning with the existing literature and reinforcing the significance of the identified necessary conditions. In the African region, both EE and SE displayed consistency slightly below the threshold of 0.8 but still met the minimum threshold recommended by [17,23]. Similarly, all conditions in the American region exhibited consistency above 0.8, with EE and Lit surpassing 0.9. All conditions were deemed necessary for Asia, with PE and SE reaching consistency levels above 0.9, highlighting their significance in the region's educational landscape. While all conditions were necessary in Europe, three conditions (EE, SE, and Lit) exceeded 0.9 consistency, indicating their paramount importance in achieving SDG 4.

This study also aimed to identify sufficient conditions for achieving SDG 4. This assessment was made at the global and regional levels to determine whether the sufficient conditions are (or are not) the same for different world regions. The results revealed notable disparities in the conditions influencing SDG 4 attainment among regions, highlighting that there are regional disparities in the factors that contribute to the achievement of SDG 4, suggesting that global policies or interventions aiming to promote education might need to be tailored to specific regional contexts, recognizing the varying importance of economic and social factors. Globally, the participation rate in organized learning one year before the official primary entry age (EE) and the lower secondary completion rate (SE) emerged as sufficient conditions for achieving SDG 4, with SE being slightly more influential. The consistency of these findings suggests their robustness and importance on a global scale. With these results, it is possible to conclude that our first hypothesis cannot be rejected, i.e., there are identifiable sufficient conditions for achieving higher levels of quality education (SDG 4) globally.

Regionally, Africa displays a reliance on EE and its combination with the net primary enrollment rate (PE) for SDG 4 attainment. The relevance of EE as a sufficient condition for achieving SDG 4 underscores the importance of pre-primary organized learning in facilitating educational progress. This result suggests that early childhood education is crucial in laying the foundation for lifelong learning and academic success. The social implication is that investing in early childhood education can improve cognitive and socio-emotional development, potentially reducing inequality in educational outcomes. In contrast, EE emerges as a sufficient condition for achieving SDG 4 for the American and European regions. The Asia region exhibits a more diversified approach, with EE, SE, and literacy rate (Lit) all being identified as sufficient conditions for the achievement of SDG 4, meaning that all of them (per se) play significant roles.

For all the world regions, EE emerges as a sufficient condition for achieving SDG 4, meaning that this factor contributes to a more solid educational base. This result is aligned with several studies (see, for example, [33,34]) which highlight the long-term

benefits of EE for children's development and in terms of impacts on income, contributing to the formation of informed and active citizens, who are more likely to get involved in sustainability initiatives and contribute to the development of their communities. In short, investing in EE benefits individual children and strengthens the foundations for sustainable and informed societies, making it a crucial approach to achieving SDG 4.

The PE does not emerge as a sufficient condition per se for any world region or the world level, which could be a sign of low commitment to universal access to basic education. The SE can be influenced by several factors, including the quality of education, employment opportunities after completing secondary education, and socio-economic barriers. Thus, the world in general (here represented by the whole sample) and, particularly, the Asia region may be better prepared to provide quality education and promote educational advancement, as they are the only ones for whom SE was identified as a sufficient condition to the achievement of the SDG 4.

Finally, considering that the Lit reflects the level of reading and writing skills in a given age group, and regions with high literacy rates generally have greater access to education, educational resources, and learning opportunities, Asia presents a distinctive pattern for the remaining regions analyzed.

These findings, which demonstrate significant regional variations in the sufficient conditions for achieving quality education, allow us to conclude that our second hypothesis is supported.

This research underscores the need for region-specific strategies, as shown by the differing sufficient conditions for achieving SDG 4 in various parts of the world. This regional variation emphasizes the importance of context-sensitive approaches in policy formulation to address educational disparities effectively and promote sustainable development.

Our findings have economic, social, and political implications. In terms of economic implications, investment in pre-primary education is crucial, as this lays the foundation for future educational success and contributes to the development of informed and active citizens. Targeted economic support for early childhood education programs can enhance educational access and quality. Concerning the social implications, access to quality education and literacy are essential for SDG 4 attainment. Promoting gender equality, inclusive education, and literacy programs can foster social cohesion and human development. Addressing social inequalities, particularly in regions with low social empowerment indicators, requires targeted policies and interventions to ensure equitable access to education for all. Finally, regarding political implications, policymakers must consider these regional variations when formulating strategies and allocating resources to achieve SDG 4. Implementing targeted interventions that address specific regional needs and challenges can enhance the effectiveness and efficiency of educational initiatives. Recognizing the diversity of conditions influencing education attainment globally, collaboration among nations, international organizations, and stakeholders becomes crucial. Sharing best practices, resources, and knowledge can help address regional disparities and accelerate progress toward achieving SDG 4 globally. This study points to the broader implications of these findings for global educational policy. By recognizing and addressing the unique educational needs and priorities of each region, policymakers can better allocate resources and implement targeted interventions that are more likely to yield significant improvements in educational outcomes.

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