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Does geographical location impact educational disparities among Ecuadorians? A novel two-stage inequality decomposition method

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The aim of this paper is to assess the extent of educational disparities among Ecuadorians attributed to their geographical location. For this purpose, a novel two-stage hierarchical decomposition of inequality for the half of the square of the coefficient of variation is introduced. This method, an extension of the one-stage (within/between) decomposition, is applicable to variables that can take the value zero, such as the 'years of schooling' variable. Using microdata bases from Ecuador's National Survey of Employment, Unemployment and Underemployment (encompassing all twenty-four provinces and four regions in 2014 and 2021), we estimated the 'years of schooling' for individuals aged 24 and over, determining provincial, regional and national mean values. The proposed method allows the identification of the extent to which educational disparities among Ecuadorians (total inequality) can be attributed to differences between provinces and regions (spatial inequality), and the extent to which such educational inequality is due to variations among individuals within provinces. Moreover, it measures the educational inequality within each province and evaluates the contribution of each province to intra-provincial inequality. The results indicate that, although spatial inequality increased between the study years, total educational inequality decreased. This is because the contribution of spatial inequality to total inequality was practically negligible compared to the influence of disparities among individuals within provinces. Consequently, the reduction in the intra-provincial inequality is the reason for the decrease in educational differences among Ecuadorians. The findings potentially reflect individual-focused policies, socioeconomic features of Ecuador's provinces and align with the official educational statistics.

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Introduction

According to the human development approach (Sen, 1980, 1988, 1989), reducing inequalities is both the goal and the means to human development (Stewart, 2016; Nag and Pradhan, 2023). Although most studies on inequality focus on the economic dimension of human development, there is a growing body of literature on the education dimension through measures like the standard deviation, the Gini index, or the indices derived from the concept of entropy (for a review of these studies, see, for example, Banzragch et al., 2019 or Dadon-Golan et al., 2019 and more recently Luo et al., 2022).

Geographic location significantly impacts inequality (Shorrocks and Wan, 2005), highlighting the need to address spatial inequality alongside individual inequality (Paredes et al., 2014; Stewart, 2016). Territorial disparities within a country not only increase inequality among individuals (Modrego and Berdegué, 2015) but also influence socioeconomic outcomes (Achten and Lessmann, 2020). Therefore, analysing differences at the subnational level is crucial for understanding and addressing these disparities.

This is particularly relevant when considering spatial educational inequality, as the economic status of a country's subnational units does not always align with their standing in other well-being dimensions, such as health or education (Otero-Bahamon, 2019). The geographical dimension of educational inequality highlights the influence of factors such as location, economic conditions, infrastructure and the distribution of resources across territories. These spatial factors impact access to education, available opportunities and ultimately, the educational outcomes for students (Mishra et al., 2023). In this regard, academic literature underscores the importance of geographical location in shaping educational inequalities, with various perspectives and methodologies being used to analyse the spatial dimension of educational inequality. For example, Fry et al. (2018) built multidimensional empirical indicators for the provinces of Thailand, while Delprato et al. (2024) highlighted the significance of the spatial dimension in educational disparities and calculate attainment indicators in sub-Saharan Africa. Mishra et al. (2023) conducted a descriptive analysis of the key geographical factors that drive spatial inequality in educational attainment. Using the Gini index, Senadza (2012) examined regional educational inequality in Ghana, and Agrawal (2014) analysed educational inequality in the urban and rural sectors of India, while Luo et al. (2022) explored educational inequality in China from a regional perspective. Applying the Theil index, Karahasan and Uyar (2009) studied the spatial distribution of education and regional inequalities in Turkey, and Rodríguez-Pose and Tselios (2011) analysed educational inequality across European regions. The role of geographical factors in educational inequality has also been studied using spatial econometric analysis (for a review, see Chocholatá and Furková, 2017). For instance, Niranjan (2020) explored the influence of the spatial dimension on educational development in India through this methodology. Similarly, Loaiza Quintero and Hincapié Vélez (2016) used non-parametric methodologies to examine educational differences among Colombian municipalities. These examples represent just a sample of the broader research that highlights its importance in understanding educational disparities, while further emphasising the need for targeted subnational analysis.

Nevertheless, it should be noted that, when analysing subnational disparities, the focus is sometimes on the variability in territorial average values, often due to data limitations (Akita, 2003; Rodríguez-Pose and Tselios, 2011; Fry et al., 2018). While this approach reflects certain dynamics of inequality, it does not clarify whether differences arise from the geographical location of individuals or from disparities among individuals within those territories (Novotný, 2007). As noted by Panori and Psycharis (2019), this is particularly relevant when designing subnational policies, as territorial averages frequently conceal significant disparities within territories, which could influence the evolution of spatial inequality over time. In line with this, as Metwally and Jensen (1973) observe, territorial averages fail to capture individual differences, potentially masking the true evolution of inequality. For example, a reduction in territorial means may coincide with growing disparities among individuals within those territories. It also worth noting that spatial units within a territory can exhibit different patterns and trajectories of spatial inequality (Park et al., 2023).

This highlights the need to go beyond territorial averages whenever data is available, calling for a more detailed analysis of inequality. Where possible, one approach is to use data at different levels of territorial disaggregation to assess spatial inequality across various geographical scales and its contribution to total inequality. This can be achieved through the use of additively decomposable measures, such as generalised entropy indices (Akita 2003; Paredes et al., 2014)[1]. Therefore, decomposing inequality according to the territorial structure (e.g., country, region, or province) is an effective method for identifying the contributions of different sources of inequality to overall inequality (Luo et al., 2022), offering a more detailed insight into geographical disparities at finer levels (Paredes et al., 2014; Dutt et al., 2020). Furthermore, when the individual is the primary unit of analysis, this approach provides a more comprehensive understanding of inequality by revealing the specific contributions of both spatial and individual disparities to total inequality. The importance of these inequality decompositions is well-supported from a public policy perspective, particularly in countries with multiple administrative levels, where a multi-stage decomposition of inequality would be ideal for addressing this level of disaggregation. In such cases, a detailed inequality decomposition serves as a valuable tool for designing and implementing effective territorial policies (Paredes et al., 2014). This approach is particularly crucial in the educational sphere, where examining spatial inequality allows for the identification of subnational areas lagging behind in educational development (Maliti, 2019), providing policymakers with insights into where targeted interventions are most needed. This is especially relevant in countries with centralised state governments.

This is the case of Ecuador, the Latin American country focused on in this study. Ecuador is an upper-middle income nation (World Bank, 2022a) which has seen reduced economic inequality since the early 21st century (Gachet et al., 2019). Simultaneously, it has made strides in education, notably achieving top results in the Programme for International Student Assessment for Development (PISA-D)[2] among participating countries in 2014 (Organisation for Economic Co-operation and Development [OECD], 2018a). The country's educational advancement is evident in the literacy rate, rising from 88.3% in 1990 (the year of the first Human Development Report of the United Nations Development Programme [UNDP]) to 93.6% in 2020 (World Bank, 2022b).

Despite these advances, the Ecuadorian central government faces challenges in reconciling territorial differences among 14 nationalities and 18 ethnic identities, which are unevenly distributed across four natural regions and 24 provinces. Additionally, a considerable portion of the Ecuadorian population lives in rural areas. It is not surprising, therefore, that subnational analyses reveal disparities among Ecuador's provinces. For instance, El Oro and Guayas recorded literacy rates of 97.6 and 95.5% in 2020, respectively, while Chimborazo and Bolívar had rates of

79.4 and 82.1% (*Consejo Nacional para la Igualdad Intergeneracional* [CNII], or National Council for Intergenerational Equality, 2023). Given Ecuador's complex landscape and the significant educational disparities across subnational units, analysing these inequalities is crucial to help policymakers design effective strategies to mitigate them. In this sense, the justification for the implementing development policies in a country requires the analysis of its internal inequalities (Martín-Mayoral, 2008; Iammarino et al., 2019). However, the academic literature has not sufficiently analysed this issue to date.

This study addresses this gap, trying to assess the scope of educational disparities among Ecuadorians attributable to their geographical location. This leads to raising the following research objectives regarding Ecuadorian educational disparities: first, to analyse the evolution of educational attainment in Ecuador, its regions and its provinces; second, to assess the evolution of educational inequality in Ecuador; third, to determine the role of the spatial component (regional/provincial) in total educational inequality; and, finally, to examine the extent of differences in educational attainment among individuals within provinces.

To reach these goals, we utilise Ecuador's *Encuesta Nacional de Empleo, Desempleo y Subempleo* (ENEMDU, or National Survey on Employment, Unemployment and Underemployment). Using the survey's microdata allows us to estimate the 'years of schooling' variable at various levels –national, regional, provincial and individual. To measure educational differences among Ecuadorians, we use the half of the square of the coefficient of variation. This inequality measure is particularly suited for this analysis because it is both additively decomposable (Bourguignon, 1979) and population-weighted, providing a robust measure of spatial inequality (Ezcurra and Rodríguez-Pose, 2013; Akita and Miyata, 2018), and can be applied to variables that take the value zero, such as 'years of schooling'.

This work contributes to inequality studies in three distinct ways. First, it provides a comprehensive overview of Ecuador's educational attainment and the disparities among individuals (total inequality) from 2014 to 2021, filling a gap in the literature on educational inequalities in Latin American and Caribbean (LAC) countries. Second, it introduces a two-stage hierarchical decomposition method for the half of the squared of the coefficient of variation. The availability of individual-level microdata allows for the decomposition of inequality at both spatial and individual levels, offering a more detailed analysis of educational disparities. However, traditional methods, such as those proposed by Gustafsson and Shi (2002) and Akita (2003) for the Theil index and the mean log deviation, rely on logarithms, making them unsuitable for variables that take zero values, such as 'years of schooling'. To address this limitation, the two-stage hierarchical decomposition introduced in this paper is appropriate for this type of variables, offering a more accurate and detailed picture of total inequality. The methodology is also versatile and can be applied to other territorial hierarchies or variables, enhancing the robustness of existing decomposition methods. Third, by applying this decomposition to Ecuador, this study deepens our understanding of how spatial and individual disparities contribute to total educational inequality and how these contributions have evolved. This approach is not only relevant to the Ecuadorian context but can also be extended to other international settings, providing valuable insights into spatial educational inequalities. While similar decompositions have been used in the study of spatial economic inequalities (e.g., Paredes et al., 2014; Akita, 2017), this research is, to the best of our knowledge, the first to apply these methods to the analysis of educational both in this and other contexts.

The remainder of the paper is structured as follows: After this introduction, we present the theoretical framework. Secondly, we outline the data source employed for the analysis. Thirdly, we show the estimation procedure of the variable 'years of schooling', along with the new methodological proposal for the hierarchical decomposition of total inequality, tailored specifically for the analysis of educational inequality in Ecuador. Fourthly, we (i) estimate educational attainment in Ecuador, (ii) measure educational inequality within the country and (iii) conduct a spatial and intra-provincial analysis of this educational inequality. Lastly, we provide a discussion and conclusions section.

Theoretical background

Impact of geographical location on education inequality. Geographical location, i.e., the spatial dimension of inequality, plays a significant role in shaping (Gachet et al., 2019) and structuring social inequalities (Genta et al., 2022). These authors point out that an individual's place of birth or residence determines their opportunities and that social inequalities crystallise in the territory. Therefore, taking the geographical location into account helps to understand the origin of such inequalities (Canelos Salazar et al., 2020). Given that the geographical location is an inherent characteristic of an individual, inequality should be assessed from a spatial perspective (Venables, 2005; Paredes et al., 2014). This analysis must consider the systematically associated advantages and disadvantages of geographical location, which involve factors such as climate and environmental quality (Shorrocks and Wan, 2005).

As interest in the spatial dimension of inequality grows within social sciences, the impact of spatial factors –particularly neighbourhood effects– has become an important focus in education research (Wei et al., 2018). In this vein, there is scientific evidence relating geographical location with the educational outcomes of the population (Otero et al., 2017), and consequently, with educational inequality (see Butler and Sinclair, 2020, for a critical review). Thus, educational attainment is significantly influenced by the location in which individuals reside, such as their neighbourhood, region, or country (Zangger, 2018). Geographical location not only influences educational opportunities (Freytag and Mössner, 2022) and educational outcomes (Otero et al., 2023) but also conditions the influence of other variables such as individual characteristics or type of school (Gutiérrez-de-Rozas et al., 2022a). In this sense, the interest in spatial location sometimes lies in its association with many other important influences, such as climate conditions, infrastructure, natural resources, governance structures and even cultural traditions (Shorrocks and Wan, 2005).

Among the geographical locations, it is worth mentioning that, although the causal relationship between neighbourhood effects and educational outcomes was uncertain until recently (Nieuwenhuis et al., 2013; Levy, 2021), there is increasing agreement in the literature that the socioeconomic environment of an individual's neighbourhood significantly impacts their educational achievement (e.g. Sirin, 2005; Liu et al., 2020; Levy, 2021). For instance, the location and accessibility of schools and universities play a crucial role in academic performance. Rural, remote and disadvantaged areas often face barriers to accessing educational infrastructure and transportation, resulting in lower achievement levels (Mishra et al., 2023). Additionally, environmental risks like violence, crime and pollution significantly shape neighbourhood conditions. Students living in areas with high environmental risks may experience health problems, anxiety, and safety concerns, which can hinder both their academic performance and overall well-being (Mishra et al., 2023). Similarly, living in neighbourhoods with high levels of violence adversely affects child development (e.g. Fry et al., 2018; McGuire and Jackson, 2018; van Dijk et al., 2020), students' cognitive

abilities, and their overall academic performance (Levy, 2021). Further evidence shows that children in violent neighbourhoods face negative outcomes, such as lower scores on standardised tests, poorer cognitive performance and reduced school attendance (Schwartz et al., 2022). In addition, crime rates and safety concerns also impact educational outcomes, including dropout and enrolment rates (Chávez and Aguilar, 2021; Mishra et al., 2023), as growing up in violent societies can hinder the development of citizenship skills (Resino et al., 2021). Moreover, studies have shown that pollution exposure negatively affects children's cognitive development, leads to health issues and contributes to absenteeism from school, all of which directly influence academic outcomes (for a review, see Wei et al., 2018). Considering the relational perspective, alongside to the family environment, the effects of collective socialisation, including the influence of local social networks, impact educational outcomes. (e.g. Zangger, 2018; Gerhard et al., 2022). Moreover, access to educational facilities contributes to students achieving academic success (Otero et al., 2023).

In LAC countries, educational inequality is a persistent issue influenced by several factors, with geographical location factor playing a crucial role. Geographic location significantly impacts access to and quality of education, particularly distinguishing between urban and rural context. In cities, districts or neighbourhoods, educational disparities are more pronounced when comparing rural and urban areas (Freytag and Mössner, 2022). Children from rural areas are less likely to attend school compared to their urban peers, and those who do enrol often receive lower quality education (Resino et al., 2021). For instance, while 66.6% of urban students in LAC countries completed upper secondary education in 2020, only 46.4% of rural students achieved this goal (United Nations Children's Fund [UNICEF], 2022).

Lastly, it is important to note that, as is common in most inequality decompositions, the within-group component tends to be larger than the between-group component, particularly when the analysis is conducted within a single country (Shorrocks and Wan, 2005; Novotný, 2007), except in the case of the urban/rural grouping (Shorrocks and Wan, 2005)[3]. Kanbur (2006) also supports this finding, observing that the within-group component generally surpasses the between-group one, with evidence showing that the latter rarely exceeds 15%, and is often even lower. Despite its relatively small contribution, between-group differences should not be overlooked, as these disparities can significantly impact social stability or be deemed unacceptable from a normative standpoint.

Building on this, it is expected that differences within territories (individual inequalities) are more influential in generating educational inequality than differences between territories (spatial inequalities). In this line, scientific evidence reveals that the influence of geographic area characteristics is usually smaller than that of individual characteristics (Otero et al., 2023). The lesser contribution of spatial inequality could be explained by the fact that educational inequalities may arise from a variety of factors that directly impact academic performance beyond geographic circumstances. In this sense, as highlighted in the review of 80 meta-analyses published between 1994 and 2019 (Gutiérrez-de-Rozas et al., 2022b), various personal variables, such as intelligence, health and students' prior performance, seem to affect academic outcomes, regardless of spatial factors. Additionally, family aspects such as father absence or socio-economic status, along with school and teacher-related variables, like classroom climate and teaching quality, play a significant role in shaping students' academic performance.

Some studies (OECD, 2018b, 2023, 2024a, 2024b) have highlighted that all these factors are significant, easily identifiable and must be considered in educational policies. There are established mechanisms, such as those outlined by the OECD (2018b), which focus on certain aspects that may affect educational inequalities. These include increasing financial resources for education based on efficiency and effectiveness criteria; improving teaching quality through strategies aimed at motivating, attracting, developing and retaining talent in the teaching profession (OECD, 2024a), while also enhancing basic and ongoing teacher training; ensuring access to early childhood education, as the early years are crucial for skill development and learning (OECD, 2023), while providing support to low-income families; and mobilising social action tools to reduce educational inequalities related to the socioeconomic status of parents and students, promoting equal opportunities and preventing low educational attainment from being passed down from generation to generation (OECD, 2024a, 2024b), among others factors. Additionally, institutions play a key role in how societies distribute the benefits and costs of public policies (Porter, 1990; Acemoglu and Robinson, 2012) by examining the inner workings of the 'black box' of educational systems and teaching-learning processes, where decisions, actions, resources, people and interactions come together to produce the desired outcomes (Hill and Hupe, 2021).

The context of Ecuador. Ecuador aims to achieve the targets of Goal 4 of the 2030 Agenda for Sustainable Development by enhancing human capital to combat global poverty (Brutti and Sánchez-Torres, 2022). This country also aligns with the 2030 Agenda in its commitment to eradicating internal inequalities (*Secretaría Nacional de Planificación* [National Department of Planning], 2021). The *Buen Vivir*[4] (Good Living or Living Well) policies emphasise education as a vital component of well-being prioritising the reduction of inter-territorial disparities (Ambrós-Pallarés et al., 2023; Izurieta and Ramírez-Álvarez, 2017; Sarmiento, 2017). Like other LAC nations, Ecuador must tackle issues of fair access to pre-school, technical and higher education (Economic Commission for Latin America and Caribbean [ECLAC], 2022) and address high school dropout rates with improved early warning systems and preventive strategies (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2013). Additionally, eradicating child labour, which limits educational and developmental opportunities, remains a significant challenge (Vásconez et al., 2015).

The *Plan Decenal de Educación* (Ten-Year Education Plan) 2006-2015 (*Ministerio de Educación y Consejo Nacional de Educación* [Ministry of Education and National Education Council], 2007) aimed to eradicate illiteracy by universalising pre-school and primary education, achieving a 75% graduation rate in secondary education and improving infrastructure and teacher training (Angel-Urdinola and Jibaja, 2018; Ray and Kozameh, 2012). The subsequent *Plan Decenal de Educación* (Ten-Year Education Plan) 2016-2025 (*Ministerio de Educación* [Ministry of Education], 2017) continues these efforts, with policies such as free education measures, including the provision of textbooks, uniforms and daily meals in schools (Guijarro-Garvi et al., 2022). The decentralisation process, intensified by the 2008 Constitution, aimed to pinpoint educational needs and address citizen demands, though its decision-making capacity remains limited (Ojeda Segovia, 2000; Shebell and Moser, 2019). The *Bono de Desarrollo Humano* ([BDH] or Human Development Voucher) supports school attendance for children in poverty by providing direct monetary compensation to households, incorporating co-responsibilities in education, health, child labour and housing (*Decreto Ejecutivo* [Executive Decree], 2003, 2019; Lucero and Burbano, 2018).

As previously mentioned, Ecuador faces the ongoing challenge of harmonising territorial differences among its nationalities and ethnic identities. According to the latest 2010 *Censo de Población y Vivienda* (Population and Housing Census) (*Instituto Nacional de Estadística y Censos* [INEC], or National Department of Statistics and Census, 2010), the population projection for 2020 showed an approximate figure of 17.5 million Ecuadorians spread amongst the different ethnic groups (Villacís and Carrillo, 2012). Most of population self-identify as Mestizos (71.9%), followed by Montubios (7.4%), Afro-Ecuadorians (7.2%), Indigenous (7.0%) and White (6.1%). Although, the official language of Ecuador is Spanish, *kichwa* and *shuar* are ancient official languages of intercultural relation recognised by the 2008 Constitution of Ecuador (*Asamblea Nacional de Ecuador* [National Assembly of Ecuador], 2008). Also, more than 36% of the Ecuadorian population lives in rural areas (World Bank, 2022b). This diversity poses challenges to the education system, particularly in addressing dropout rates among ethnic minority students (Pachay-López and Rodríguez-Gámez, 2021). The *Modelo del Sistema de Educación Intercultural Bilingüe* (MOSEIB, or Model of the Ecuadorian Intercultural Bilingual Education System) aims to integrate diverse cultural knowledge and diminish national inequalities (*Ministerio de Educación* [Ministry of Education], 2013).

Socio-spatial inequality in Ecuador is evidenced in two ways: firstly, there is a significant concentration of population and economic activity in a few territories of the country. Secondly, there are disparities in living standards across the various territories (Genta et al., 2022). The differences between territories are perpetuated and exacerbated through a cycle of interrelated factors such as poverty and productive capacity (Canelos Salazar et al., 2020). Rural areas experience nearly double the poverty rate compared to urban areas (47.9 versus 25.1% in 2020) (CNII, 2023). Additionally, some Ecuadorian provinces have relatively higher levels of economic development and lower levels of poverty (Álvarez-Gamboa et al., 2021; CNII, 2023). Provinces like Pichincha, Guayas, El Oro and Galápagos show higher economic development and lower poverty levels, whereas Bolívar and Chimborazo remain among the poorest, with high child labour rates[5] and significant portions of their populations engaged in agriculture or unskilled jobs (Álvarez-Gamboa et al., 2021; CNII, 2023; Mendieta et al., 2015).

From all the aforementioned, the following hypotheses can be derived:

Hypothesis 1: The educational attainment in Ecuador, its regions and its provinces increases during the study years, reflecting improvements in overall educational levels.

Hypothesis 2: Educational inequality in Ecuador decreases between the study years, indicating a reduction in disparities in educational attainment.

Hypothesis 3: Educational disparities among Ecuadorian individuals within provinces have a more substantial impact on overall educational inequality compared to spatial inequality (between provinces and regions).

Data. The current study utilised microdata from the ENEMDU databases for 2014 and 2021, conducted by Ecuador's National Institute of Statistics and Census (INEC, 2022a). The choice of 2014 as the starting year of the study was guided by the fact that it was the first year with complete geographical coverage in all provinces and regions of Ecuador (for more detailed information on the survey's sample design, refer to INEC, 2021).

The ENEMDU falls under the category of labour force surveys (World Bank, 2019), focusing primarily on labour-related issues while also encompassing demographic and socioeconomic aspects of the surveyed population. Alongside living condition surveys, labour surveys are considered among the most suitable sources for analysing inequality (Gasparini et al., 2012). Given the presence of diversity among individuals within a country, it is essential to have high-quality data sources with extensive spatial disaggregation (Wardrop et al., 2018). The geographic coverage provided by the ENEMDU renders it an instrumental survey in identifying diverse characteristics within the Ecuadorian population based on their respective places of residence.

Measures and methods

Measuring educational attainment in Ecuador. We selected the 'years of schooling' variable for our analysis based on several compelling reasons. Firstly, it is a widely recognised measure for educational attainment, notably featured in studies of economic growth by Barro and Lee (1993, 1996, 2013). Secondly, increased years of schooling not only improve access to the labour market but also correlate with higher levels of well-being (Orellana et al., 2016). Thirdly, its inclusion in the construction of the Human Development Index (HDI) by the UNDP since 2010 (UNDP, 2010, 2022) aligns our study within the context of human development. Fourthly, it serves as a pivotal educational indicator in poverty measurement across LAC nations (Santos and Villatoro, 2018). Lastly, the 'years of schooling' variable provides a more accurate representation of Ecuador's educational reality compared to other metrics, such as schooling rates, which might be influenced by high dropout rates prevalent in LAC countries (Lorente, 2019). It is essential to note that our findings remain unaffected by potential consequences resulting from the COVID-19 pandemic on the Ecuadorian educational system. This is because our analysis focuses on individuals aged 24 years and over who completed their education before the pandemic.

To estimate the values of the variable 'years of schooling', we started by identifying individuals aged 24 years and over (hereafter individuals) from question 'age' of ENEMDU (INEC, 2020), in both databases (60,962 and 54,822 in 2014 and 2021, respectively) (INEC, 2022a).

To spatially locate individuals, we utilized Ecuador's hierarchical geographical structure, comprising provinces and regions. Ecuador's territory encompasses four regions: three on the mainland (Sierra, Costa and Amazonía), and the fourth being the island region of Galápagos in the Pacific Ocean[6]. Presently, the country is organised into twenty-four provinces (listed in brackets): Sierra (Azuay, Bolívar, Cañar, Carchi, Cotopaxi, Chimborazo, Imbabura, Loja, Pichincha, Santo Domingo de los Tsáchilas and Tungurahua); Costa (El Oro, Esmeraldas, Guayas, Los Ríos, Manabí, and Santa Elena); Amazonía (Morona Santiago, Napo, Pastaza, Zamora Chinchipe, Sucumbíos, and Orellana), and the single-province region of Galápagos. Each individual is assigned an expansion factor corresponding to the number of people they represent (refer to Table A1 in the online Supplementary Information Section). Using the survey's expansion factors, we estimated the population count for each province and region for both years.

We then combined individuals' responses to the questions 'level of education' and 'highest year of education passed' to estimate the number of years of schooling for each individual. The methodology, in line with the Ministry of Education of Ecuador's guidelines (*Ministerio de Educación*, 2015), is presented in Table 1. This approach aligns with educational reforms enacted in the country in recent years (refer to Table A2 in the online Supplementary Information Section)[7].

To calculate provincial, regional and national measures of central tendency (mean, median and mode) regarding educational attainment, we multiplied each individual's number of

Table 1 Procedure for estimating the variable 'years of schooling' (2014 and 2021).

Level of education	Highest year of education passed (y)	Number of years of schooling
None	-	0
Primary Education[a]	1, 2, 3, 4, 5, 6	$1+y$
Secondary Education[a]	1, 2, 3, 4, 5, 6	$7+y$
Basic Education[b]	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	y
Middle Education[b]	1, 2, 3	$10+y$
Non-university Higher Education	1, 2, 3	$13+y$
Higher Education	1, 2, 3, 4, 5, 6, 7, 8	$13+y$
Postgraduate	1, 2, 3	$18+y$

NOTES: y = number of years of the answer;
SOURCE: Authors´ own based on the methodology proposed by the *Ministerio de Educación* (2015).
[a]Former Education System (1983 *Ley Orgánica de Educación* [Education Act]);
[b]Current Education System (2011 *Ley Orgánica de Educación Intercultural* [LOEI, or Intercultural Education Act], amended in 2021 by the *Ley Orgánica Reformatoria de la Ley Orgánica de Educación Intercultural* [LOEI Reform Act]; For individuals trained in previous education systems, the Ecuador's National Survey of Employment, Unemployment and Underemployment considers the number of years of schooling to be equal to 2 y, when $y = 0, 1, 2$ and $3 + y$, when $y = 3, 4, 5, 6, 7, 8, 9, 10$.

years of schooling by their corresponding expansion factors. The resulting mean values were utilized for the assessment and decomposition of educational inequality, as will be seen below. The expansion factor was also used to estimate the proportion of individuals with zero years of schooling at the national, regional and provincial levels.

Measuring and decomposing educational inequality in Ecuador. To measure educational differences among Ecuadorians, that is, Ecuadorian educational inequality[8], we used the half of the square of the coefficient of variation. This inequality measure belongs to the family of generalised entropy measures (Cowell, 1995) and fulfils the desirable properties of an inequality measure (independence of scale and population size or Pigou-Dalton transfer principle) (Bourguignon, 1979). It is also additively decomposable, as the Theil index or the mean log deviation are. As mentioned earlier, unlike these indices, the half of the square of the coefficient of variation does not include a logarithm in its expression. Hence, it presents an advantage as it can be applied to variables that take the value zero, such as the variable 'years of schooling'.

To identify how much of the educational inequality among Ecuadorians (total inequality) can be attributed to spatial inequality, and how much to inequality among individuals within each province, we conducted a two-stage[9] decomposition analysis of inequality. When the territorial structure of a country is taken into account, inequality decompositions in two or more stages are hierarchical decompositions where the primary units of study are grouped into two or more levels (Akita, 2003), following a decomposition sequence that cannot be reversed (Akita and Miyata, 2018). These decompositions offer a much more detailed view of geographical inequalities at a finer level (Paredes et al., 2014). In particular, when the primary unit of analysis is the individual, multi-stage decomposition allows for a more comprehensive analysis of spatial inequality.

Thus, as previously mentioned, individuals in the population aged 24 and over –our primary unit of analysis– were grouped into provinces and regions, serving as our second and third units of analysis, respectively. Total inequality, quantified by the half of the square of the coefficient of variation (I), admits the following two-stage hierarchical inequality decomposition (detailed formal aspects and demonstrations can be found in the online Supplementary Information Section):

$$I = I_{BR} + I_{BP} + I_{WP}$$

Hence, total inequality stems from three distinct sources: the first component represents inequality between regions (I_{BR}) or inter-regional inequality; the second arises from inequality between provinces or inter-provincial inequality, and the third component reflects inequality within provinces, signifying inequality among individuals in each province or intra-provincial inequality. Also, it follows that:

$$I = I_S + I_{WP}$$

where I_S is the part of total inequality that is attributable to the spatial location of individuals. Moreover,

$$I_{WP} = \sum_r \sum_p w_{rp} \cdot I_{rp}$$

where we defined I_{rp} as the *Individual Inequality Index*, that is, the index that measures the inequality between individuals belonging to province p in region r. This index is actually the half of the square of the coefficient of variation of province p in region r. The coefficient w_{rp} is the provincial weighting of the index and depends on both the population of the province and the mean value of the variable in the province (see the online Supplementary Information Section for details).

Results

Educational attainment in Ecuador: country, regions and provinces. Ecuador demonstrated progress in educational attainment between 2014 and 2021, as shown by the country mean years of schooling in Table 2. All regions displayed an increase in their respective mean values during this period. Galápagos, the single-province region, exhibited the highest educational level in both years. Most provinces experienced a rise in educational attainment over the study period, except for Chimborazo (Sierra), Esmeraldas (Costa) and Orellana and Napo (Amazonía).

Table 2 displays Ecuador's mode transitioned from 7 (completed Primary Education) to 13 years (completed Middle Education) between 2014 and 2021. By 2014, all regions had a mode equal to 7 years of schooling, except the single-province region of Galápagos, with 13 years. The Sierra and Amazonía regions retained 7 years as the prevailing educational level among their populace in 2021. All provinces had an absolute mode equal to 7 years of schooling in 2014, except Pichincha (Sierra) and Galápagos, whose mode was 13 years. By 2021, Santo Domingo (Sierra), El Oro, Esmeraldas, Guayas (Costa) and Morona Santiago, Pastaza and Sucumbíos (Amazonía) also showed a shift to 13 years of schooling as the most frequent level.

In 2021, half of Ecuadorian attained at least 11 years of schooling, and all regions improved their median value during the study period, except Galapagos, which maintained it at 13 years of schooling. The 2014 provincial median values show that half of the individuals had at least: 7 years of schooling in most provinces, 10 years in El Oro and Guayas (Costa), Napo and Pastaza (Amazonía) and 13 years in Pichincha (Sierra) and Galápagos. By 2021, the number of provinces where at least 50% of individuals had completed a minimum of 10 years of schooling increased from 6 to 10. Notably, Azuay (Sierra), with its median value increasing from 7 to 12 years during the study period.

In order to complement the information regarding Ecuadorians' educational attainment provided by the measures of central tendency, Table 3 shows the proportion of individuals with no years of schooling at the national, regional and provincial levels.

Several provinces had high rates of individuals with no years of schooling, particularly in 2014. Bolívar, Cañar, and Chimborazo in Sierra and Manabí in Costa exemplify this trend. By 2021, there were improvements, except in certain provinces like Azuay, Imbabura and Santo Domingo in Sierra, Esmeraldas in Costa, or Pastaza and Zamora Chinchipe in Amazonía. Particularly striking is Imbabura in Sierra, ranking second worst after Bolívar in 2021. Sierra and Costa regions had consistent figures in both years, aligning with national data. In 2021, nearly all individuals in Galápagos had at least 1 year of schooling.

Table 2 Central tendency measures of the variable 'years of schooling' in Ecuador (2014 and 2021).

	2014			2021		
	Mode	**Median**	**Mean**	**Mode**	**Median**	**Mean**
Azuay	7	7	9.83	7	12	10.71
Bolívar	7	7	8.64	7	7	9.32
Cañar	7	7	8.66	7	7	9.15
Carchi	7	7	8.85	7	7	9.42
Cotopaxi	7	7	9.00	7	7	9.16
Chimborazo	7	7	9.26	7	7	9.06
Imbabura	7	7	9.05	7	7	9.20
Loja	7	8	10.18	7	9	10.24
Pichincha	13	13	11.06	13	13	12.31
Tungurahua	7	7	9.06	7	7	9.92
Santo Domingo	7	7	9.36	13	10	10.07
Sierra	**7**	**10**	**10.05**	**7**	**13**	**10.88**
El Oro	7	10	10.10	13	12	10.81
Esmeraldas	7	9	9.58	13	9	9.44
Guayas	7	10	10.08	13	13	10.84
Los Ríos	7	7	8.73	7	9	9.52
Manabí	7	7	8.66	7	7	9.41
Santa Elena	7	7	9.13	7	7	9.62
Costa	**7**	**9**	**9.60**	**13**	**10**	**10.30**
Morona Santiago	7	8	9.42	13	10	9.92
Napo	7	10	10.22	7	10	10.15
Pastaza	7	10	10.15	13	10	10.63
Zamora Chinchipe	7	8	9.91	7	9	10.13
Sucumbíos	7	7	9.16	13	11	10.23
Orellana	7	7	9.08	7	7	8.91
Amazonía	**7**	**9**	**9.56**	**7**	**10**	**9.89**
Galápagos	**13**	**13**	**11.51**	**13**	**13**	**12.48**
Ecuador	**7**	**9**	**9.81**	**13**	**11**	**10.51**

NOTE: Mode refers to absolute mode of the corresponding distribution; The data of Ecuador and its four regions are shown in bold.
SOURCE: Authors´ calculations based on microdata bases of Ecuador's National Survey of Employment, Unemployment and Underemployment for 2014 and 2021 (*Instituto Nacional de Estadística y Censos* [INEC], 2022a).

Educational inequality in Ecuador: spatial and intra-provincial inequality. We quantified the magnitude of Ecuadorian educational inequality and its evolution between 2014 and 2021. Additionally, we assessed the contribution of spatial and intra-provincial inequality to it.

Analysis shows Ecuadorian educational inequality decreased over the study period (Table 4). Results from the two-stage decomposition method indicate minimal contribution from both between regions and between provinces components to total educational inequality in 2014 and 2021, with the latter slightly higher. Though spatial inequality's weight grew in 2021, mainly due to increase of between provinces inequality, it remained almost negligible compared to intra-provincial differences. The almost non-existent educational inequality between Ecuadorian regions in both years is noteworthy.

Our findings also indicate that the Ecuadorian educational inequality decreased, primarily driven by a slightly larger decline in intra-provincial inequality. Although spatial inequality increased, its minimal contribution to total inequality meant this rise had little impact on the overall variation.

Table 4 also reveals the role of between regions and between provinces components in spatial inequality. Inter-provincial inequality was undeniably the primary contributor. While its relative significance diminished slightly over the analysed period, favouring a small increase in the inter-regional disparity contribution, it remained the primary source of spatial inequality in 2021.

Given the substantial contribution of inequality within provinces to total inequality, it is worthwhile to delve into provinces' educational attainment and focus on the existing educational disparities within them. Thus, Fig. 1 displays the density functions of the variable 'years of schooling' for individuals aged 24 years and over in Ecuador's twenty-four provinces, depicting their dynamics between 2014 and 2021. It provides an initial insight into the disparities among individuals within each province, further complementing the information in Table 2.

Figure 1 graphs indicate a consistent pattern in most provinces across both years, aligning with the low inter-provincial inequality weight (Table 4). In 2014, the majority of provinces displayed a right-skewed distribution. This suggests that in these provinces the proportion of individuals with fewer years of schooling than

Table 3 Percentage of individuals aged 24 and over with no years of schooling in Ecuador (2014 and 2021).

	2014	2021		2014	2021		2014	2021
Azuay	4.3	4.5	El Oro	3.6	2.5	Morona Santiago	6.8	5.6
Bolívar	11.8	10.8	Esmeraldas	5.5	5.8	Napo	3.5	2.5
Cañar	9.4	7.6	Guayas	4.3	3.3	Pastaza	6.7	7.1
Carchi	4.0	3.3	Los Ríos	7.2	7.2	Zamora Chinchipe	3.2	5.0
Cotopaxi	8.4	7.6	Manabí	8.8	8.1	Sucumbíos	5.4	4.1
Chimborazo	10.9	8.1	Santa Elena	3.8	2.9	Orellana	6.1	5.9
Imbabura	8.4	9.6	**Costa**	**5.4**	**4.5**	**Amazonía**	**5.4**	**5.0**
Loja	3.3	3.2				**Galápagos**	**3.2**	**0.2**
Pichincha	3.9	2.6				**Ecuador**	**5.4**	**4.5**
Tungurahua	5.5	4.5						
Santo Domingo	3.9	4.4						
Sierra	**5.4**	**4.5**						

NOTE: The data of Ecuador and its four regions are shown in bold. SOURCE: Authors´ calculations based on microdata bases of Ecuador's National Survey of Employment, Unemployment and Underemployment for 2014 and 2021 (*Instituto Nacional de Estadística y Censos* [INEC], 2022a).

Table 4 Ecuadorian educational inequality and its components (2014 and 2021).

2014	Total inequality 0.1297		
	Spatial inequality 0.0034 (2.6)		Within provinces inequality 0.1263 (97.4)
	Between regions inequality 0.0003 (0.2) *(8.8)*	Between provinces inequality 0.0031 (2.4) *(91.2)*	
2021	Total inequality 0.1118		
	Spatial inequality 0.0049 (4.4)		Within provinces inequality 0.1069 (95.6)
	Between regions inequality 0.0005 (0.5) *(10.8)*	Between provinces inequality 0.0044 (3.9) *(89.2)*	
Annual variation rate (%)	Total inequality -2.1		
	Spatial inequality 5.4		Within provinces inequality -2.4
	Between regions inequality 8.6	Between provinces inequality 5.1	

NOTE: Results obtained from the inequality measure half of the squared of the coefficient of variation; the figures in parentheses are the contributions of each component to total inequality (%); the figures in italics are the contributions to spatial inequality of their components (%); the annual variation rate is equal to $(\text{final value}/\text{initial value})^{1/(2021-2014)} - 1$.
SOURCE: Authors' calculations based on microdata bases of Ecuador's National Survey of Employment, Unemployment and Underemployment for 2014 and 2021 (*Instituto Nacional de Estadística y Censos* [INEC], 2022a).

the provincial mean surpassed the proportion of individuals with more years, indicating the provincial mean exceeded the median, as seen in Table 2. Additionally, the proportion of individuals with the highest education levels was small in these provinces. In 2021, a similar density shape persisted, except for El Oro (Costa), Azuay, Santo Domingo de los Tsáchilas (Sierra), Morona Santiago and Sucumbíos (Amazonía), which shifted slightly to the left, in line with the improvement experienced in their educational levels (Table 2). Esmeraldas and Guayas (Costa), Napo and Pastaza (Amazonía), Pichincha (Sierra), or Galápagos had smoother density shapes in 2014, a trend only sustained by Esmeraldas in 2021. Conversely, the density function skewed right in Napo, and left in Guayas, Pastaza, Pichincha and Galápagos. Therefore, in these four provinces, the proportion of individuals with an education level above the provincial mean outweighed the proportion of those with an education level below the provincial mean[10].

In 2021, certain provinces exhibited unimodal densities, such as El Oro (Costa), Morona Santiago, Pastaza and Sucumbíos (Amazonía), while others remained unimodal in both years, like Guayas (Costa) and Galápagos. These modes corresponded to completed Middle Education as mentioned before. Notably, Esmeraldas (Costa) displayed two soft local modes of almost the same density in both years. In Pichincha (Sierra), the local mode corresponding to completed Primary Education in 2014 vanished by 2021. However, in addition to the mode equal to 7 years for the vast majority of provinces in 2014, some of the provinces also had a local mode equal to 13 years of schooling. Consequently, while there was a concentration of individuals in these provinces whose level of education corresponded to completed Primary Education, there was also a notable proportion of individuals whose level of education was higher than the provincial mean. Examples include Los Ríos, Manabí and Santa Elena (Costa), most Sierra provinces (except Azuay and Pichincha) and Zamora Chinchipe and Orellana (Amazonía); some of them exhibited nearly non-existent local modes, particularly in 2014, like Los Ríos and Manabí (Costa), or Bolívar, Cañar, Imbabura, and Tungurahua (Sierra). Furthermore, several provinces displayed two local modes, both exhibiting similar density: one in completed Primary Education and the other in completed Middle Education, such as Esmeraldas (Costa) or Napo (Amazonía).

Finally, the density functions in Fig. 1 reveal a lack of distinct regional patterns, with provinces across different regions displaying similar density shapes, except for Galápagos. This observed resemblance in educational attainment between regions, coupled with the previously mentioned similarity between provinces, aligns with the findings of the two-stage inequality decomposition. This analysis highlights the limited impact of between regions and between provinces disparities (spatial inequality) on total inequality. On the contrary, the identification of local modes –typically two within most provinces– which concentrate a high proportion of individuals, alerts of the presence of within provinces differences.

In this context, the shape of the density functions in Fig. 1 suggests that the dispersion of the variable distribution in certain provinces, such as Chimborazo or Bolívar in the Sierra region, was greater than in the rest of the provinces in both years. This implies a higher level of inequality across individuals within these provinces. Quantifying this dispersion is essential to confirm these disparities. Additionally, these density functions do not distinctly indicate if the dispersion within each provincial distribution decreased between 2014 and 2021. This issue will also be further analysed below.

Table 5 and Fig. 2 give a detailed look at the role played by each Ecuadorian province to the within provinces component of total inequality. Table 5 displays the Individual Inequality Index (I_{rp}) for each Ecuadorian province, that is, the inequality across individuals belonging to the same province. Consistent with Fig. 1's density functions, Chimborazo and Bolívar, having the most dispersed shape, also exhibited the highest inequality in both years. These provinces, as previously noted, had the highest

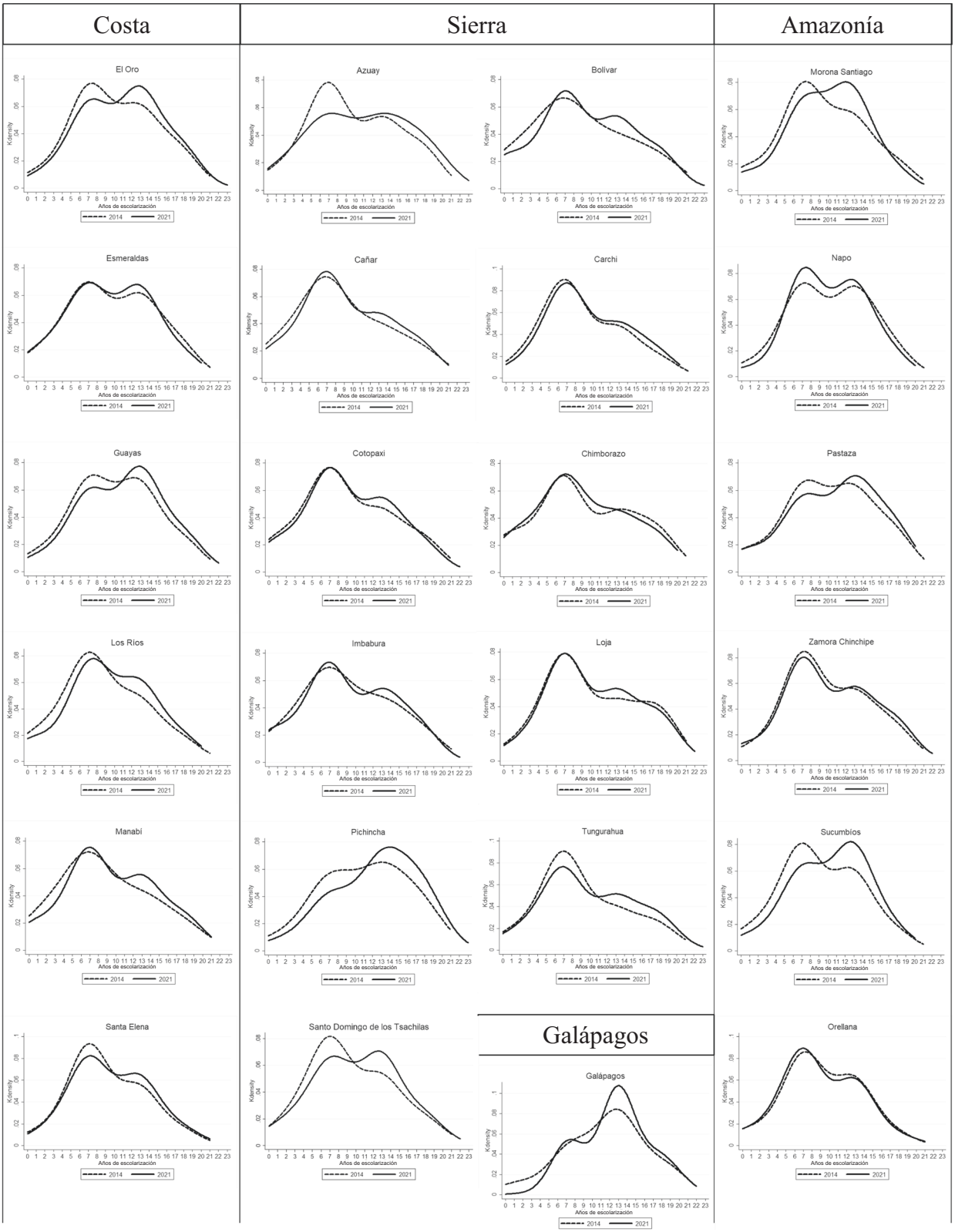

Fig. 1 'Years of schooling' distribution by province (2014 and 2021). The lines in each graph correspond to the *kernel* density function of the variable in each province for the study years. The Gaussian *kernel* function has been used (Silverman, 1986). SOURCE: Authors' calculations based on microdata bases of Ecuador's National Survey of Employment, Unemployment and Underemployment for 2014 and 2021 (*Instituto Nacional de Estadística y Censos* [INEC], 2022a).

Table 5 Individual Inequality Index for the Ecuadorian provinces (2014 and 2021).

	2014			2021			
Provinces	**Index**	**Provinces**	**Index**	**Provinces**	**Index**	**Province**	**Index**
Galápagos	0.0848	Loja	0.1309	Galápagos	0.0494	Carchi	0.1204
Napo	0.0992	Azuay	0.1320	Pichincha	0.0765	Loja	0.1217
Pichincha	0.1003	Esmeraldas	0.1326	Napo	0.0803	Los Ríos	0.1234
El Oro	0.1076	Carchi	0.1364	El Oro	0.0913	Esmeraldas	0.1286
Zamora Chinchipe	0.1103	Tungurahua	0.1484	Sucumbíos	0.0920	Azuay	0.1289
Santa Elena	0.1104	Los Ríos	0.1499	Guayas	0.0953	Tungurahua	0.1375
Guayas	0.1105	Imbabura	0.1656	Morona Santiago	0.0974	Manabí	0.1512
Orellana	0.1138	Cotopaxi	0.1708	Santa Elena	0.1035	Cotopaxi	0.1523
Pastaza	0.1215	Manabí	0.1791	Santo Domingo	0.1151	Cañar	0.1620
Sucumbíos	0.1249	Cañar	0.1851	Pastaza	0.1162	Imbabura	0.1629
Santo Domingo	0.1295	Chimborazo	0.1874	Orellana	0.1189	Bolívar	0.1690
Morona Santiago	0.1304	Bolívar	0.2047	Zamora Chinchipe	0.1190	Chimborazo	0.1764

NOTE: The provinces are ordered from the lowest to the highest value of its Individual Inequality Index.
SOURCE: Authors' calculations based on microdata bases of Ecuador's National Survey of Employment, Unemployment and Underemployment for 2014 and 2021 (*Instituto Nacional de Estadística y Censos* [INEC], 2022a).

proportion of individuals with no years of schooling and a notable proportion exceeding the provincial mean in educational attainment. Our findings show a decrease in differences across individuals among most provinces over the study period, except for Zamora Chinchipe and Orellana, which experienced slight increases in internal inequality. Interestingly, in 2014, Galápagos, Napo, Pichincha and El Oro had the least inequality between individuals, a trend that persisted in 2021. While Chimborazo and Bolívar remained the most unequal provinces in 2021, their positions relative to each other shifted.

It is worth noting that, Sucumbíos decreased its inequality in 2021, joining the five least unequal provinces. This change resulted partly from a decline in the proportion of individuals without years of schooling, as indicated in Table 3. Conversely, Imbabura dropped positions in 2021, ranking among the three most unequal provinces. Despite reducing inequality during the study period, its progress was comparatively less than provinces with similar initial inequality in 2014.

Figure 2 illustrates each province's contribution to this component. It is important to note that the within provinces component hinges on not just the inequality between individuals within each province –quantified by its Individual Inequality Index– but also on the provincial mean value and population size.

In 2014 and 2021, most contributions ranged between 0.2 and 5.4% and 0.1 and 5.9%, respectively. Pichincha and Guayas had the most substantial impact on intra-provincial inequality due to their large populations (refer to Table A1 in the online Supplementary Information Section) and their highest mean years of schooling (Table 2). Nonetheless, smaller provinces also made significant contributions to intra-provincial inequality. For instance, Manabí displayed one of the highest values of the Individual Inequality Index in both years. Despite having the lowest mean years of schooling in 2014, alongside Bolívar, its contribution remained notable. In contrast, Galápagos had the smallest impact on individual inequality, mainly due to its low inequality and small population (refer to Table A1 in Supplementary Information Section). Despite having the highest mean years of schooling in both 2014 and 2021 (Table 2), its contribution remained minimal.

Sensitive analysis. Guayas and Pichincha's high contribution to within province inequality suggests the need for a sensitivity analysis. This aims to ascertain the extent to which the educational inequality components' weight originates from the contribution of Ecuador's two most populated provinces (Permanyer and Smits, [2020], offer a comprehensive review of this type of analysis).

Table 6 presents the two-stage decomposition of Ecuadorian educational inequality excluding Guayas or Pichincha from the analysis. Remarkably, the total inequality values remained nearly unchanged compared to considering all twenty-four provinces, especially in 2021. This indicates that excluding these provinces did not notably alter total educational inequality. Despite the minor impact on inequality and its components shown by this sensitive analysis, particularly in absolute terms, focusing on the spatial component's contributions to total inequality is valuable. When Guayas was excluded, the spatial inequality component surged to nearly 6% in 2021. Conversely, excluding Pichincha reduced this contribution to 2%. This shift is due to Guayas being the most populous province and Pichincha, alongside Galápagos, having the highest mean years of schooling, factors boosting within provinces inequality's weight.

Discussion and conclusion

Using ENEMDU microdata bases, we conducted a detailed analysis of the spatial distribution and dynamics of the 'years of schooling' variable in Ecuador. We estimated this variable for individuals aged 24 years and over, determining provincial, regional and national average values. Additionally, we performed an inequality decomposition analysis, considering individuals, provinces and regions as primary, secondary and tertiary units of analysis, respectively. This approach addressed key questions regarding Ecuadorian educational disparities using a two-stage hierarchical inequality decomposition method applicable to the half of the square of the coefficient of variation.

First, our findings reveal a considerable proportion of individuals across all provinces lacking any years of schooling, validating our proposed method, applicable to variables that can take the value zero.

Second, our results show that, between 2014 and 2021, educational attainment in Ecuador, along with all its regions and nearly all provinces, experienced a notable enhancement, indicating advancements in overall education levels. In 2014, the prevalent educational level in most regions and provinces was completed Primary Education, which progressed by 2021, with a substantial number of provinces witnessing a majority completing Middle Education. This can be attributed to the education reforms implemented under the Ten-Year Education Plans

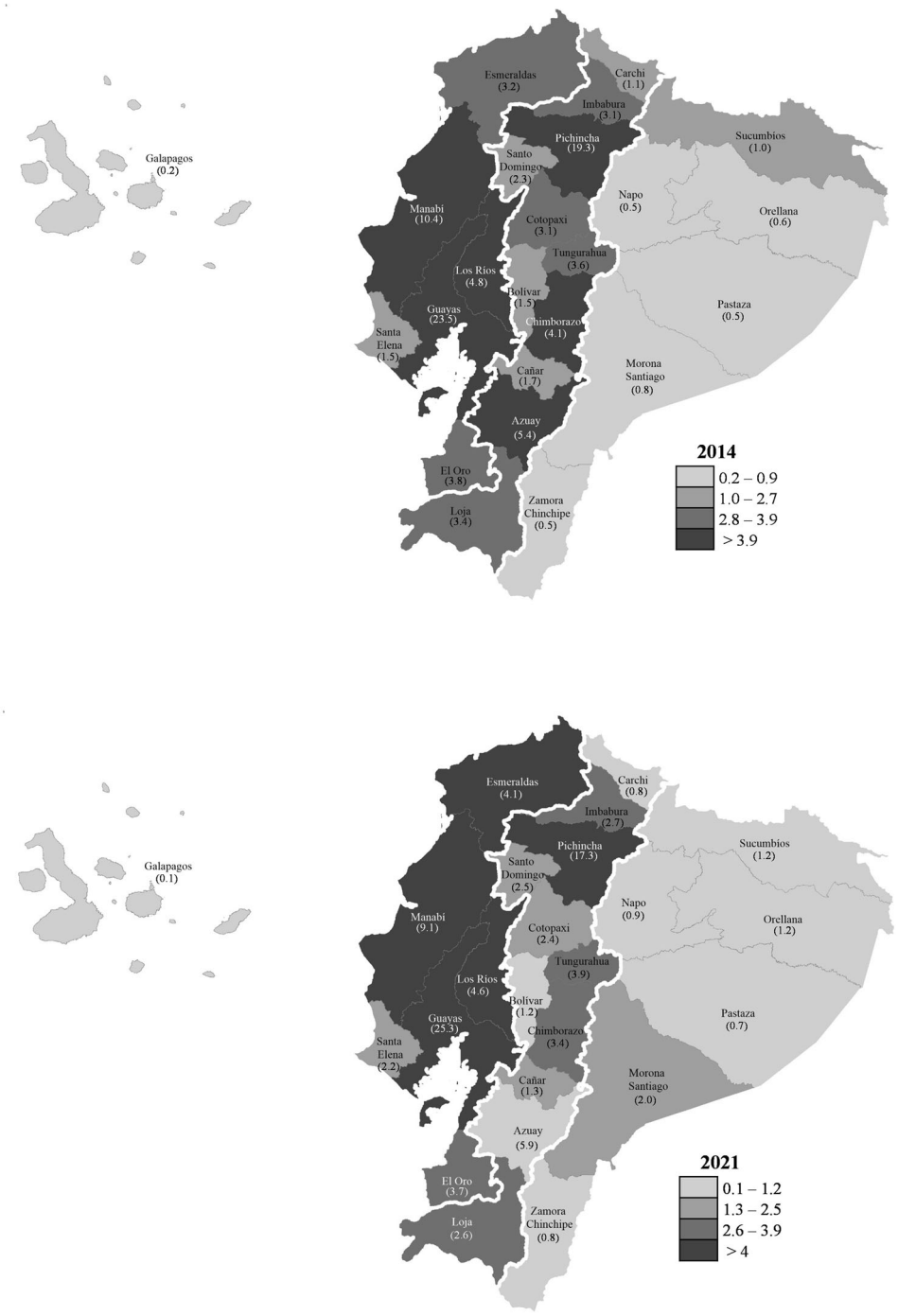

Fig. 2 Provincial contribution to the within provinces component of Ecuadorians educational inequality (2014 and 2021). The provinces are grouped by quartiles according to their contribution. SOURCE: Authors' calculation based on the microdata bases of Ecuador's National Survey of Employment, Unemployment and Underemployment for 2014 and 2021 (*Instituto Nacional de Estadística y Censos* [INEC], 2022a). The geographic representation was conducted using a GIS (Geographic Information Systems) mapping programme for which the corresponding license for use is available. A shapefile with the political limits of the provinces of Ecuador has been used in the preparation of the map. This shapefile is freely available from the website of the University of Azuay (https://gis.uazuay.edu.ec/descargas/promsa/ecuador.htm).

2006-2015 and 2016-2025, which partially achieved their goals. Additionally, Ecuador has slightly increased the percentage of public spending allocated to education in recent years, which has undoubtedly contributed to this improvement (UNESCO, 2019). The results correspond with the upward trend in the average years of schooling in Ecuador as estimated by Gachet et al. (2019) and also align with those obtained by Perosa et al. (2021) for a sample of LAC countries, which show a sustained improvement in educational attainment over the past few years. It is also worth mentioning that the trend of improving observed in Ecuadorian provinces up to 2014 (Guijarro-Garvi et al., 2022) appears to persist through 2021.

Third, overall educational inequality in Ecuador declined during the study period. This finding is consistent with the

Table 6 Ecuadorian educational inequality and its components excluding Guayas and Pichincha (2014 and 2021).

	2014			2021		
	All provinces	Without Guayas	Without Pichincha	All provinces	Without Guayas	Without Pichincha
Spatial inequality	0.0034 (2.6)	0.0045 (3.3)	0.0019 (1.4)	0.0049 (4.4)	0.0066 (5.6)	0.0023 (2.0)
Within provinces inequality	0.1263 (97.4)	0.1321 (96.7)	0.1340 (98.6)	0.1069 (95.6)	0.1115 (94.4)	0.1157 (98.0)
Total inequality	0.1297	0.1366	0.1360	0.1118	0.1181	0.1180

NOTE: Results obtained from the inequality measure half of the squared of the coefficient of variation; the figures in parentheses are the contributions of each component to total inequality (%).
SOURCE: Authors' calculations based on microdata bases of Ecuador's National Survey of Employment, Unemployment and Underemployment for 2014 and 2021 (*Instituto Nacional de Estadística y Censos* [INEC], 2022a).

literature, as an increase in the average years of education leads to a reduction in educational inequality (e.g. Yang et al., 2014). The result also corresponds with studies conducted in other LAC countries, indicating that the region's efforts to reduce educational inequalities are yielding positive results. Examples of such studies include Cuenca and Urrutia (2019), which explores educational inequalities in Peru, or Montaño and Navia (2022) in Bolivia.

Fourth, this reduction stemmed from a decrease in the intra-provincial component between 2014 and 2021, with nearly all provinces reducing inequality among individuals. The decline in individual differences within provinces during the study period can be attributed to the effectiveness of national policies aimed at individuals and compensating for existing inequalities (Perosa et al., 2021), particularly by ensuring equal access to education. Indeed, an effective approach to tackling educational inequalities involves implementing compensatory policies aimed at supporting disadvantaged population groups (Stromquist, 2004). This is the case of the BDH, which works in conjunction with the Ten-Year Education Plans as a part of the poverty eradication policy of Ecuadorian Government. Research shows that the effects of the BDH have been significant in decreasing child labour and activity rates (Edmonds and Schady, 2012), although smaller in increasing school enrolment (Schady and Araujo, 2006). However, more recent studies have found modest positive and significant impacts on secondary education completion –with these rates being higher for girls than for boys– (Araujo et al., 2018) in contrast to the absence of said impact on enrolment or labour force participation for either gender (Molina Millán et al., 2019). The existing barriers to the acceptance of this social assistance –information, compliance and psychological costs– (Rinehart and McGuire, 2017) could be the reason for this apparent failure to meet the BDH´s objectives.

Fifth, our proposed methodology shows that educational disparities among Ecuadorian individuals within provinces have a more substantial impact on overall educational inequality compared to differences between provinces and regions (spatial inequality). This finding is consistent with the fact that, regardless of the decomposition method used, empirical evidence shows that the contribution of the spatial component is seldom above 15% and is often even less (Kanbur, 2006). Overall, this result aligns with previous studies in other LAC countries, where spatial inequality has a relatively smaller contribution compared to the inequality within the respective territories (e.g. Sánchez-Torres, 2017, for income inequality in Colombia or Paredes et al., 2014, in Chile). Our finding also agrees with studies conducted in countries from other regions. For example, Agrawal (2014) found similar patterns of educational inequality decomposition in India, as did Rodríguez-Pose and Tselios (2011) in their two-stage decomposition of educational inequality for a selection of European countries.

One possible explanation for the high contribution of educational inequality among Ecuadorians within provinces is the large proportion of individuals with no years of schooling in numerous provinces in 2014, as found in this study; this proportion was by no means negligible in the provinces with the best educational performance. Even though this scenario enhanced slightly in 2021, it remains concerning in certain provinces like Bolívar or Imbabura. Additionally, the significant proportion of rural population in every Ecuadorian province may contribute to inequality within provinces. For example, Guayas, the province with the lowest percentage of rural residents in 2021 (15.2%) (INEC, 2022b), had one of the country's lowest overall illiteracy rates[11] in 2020 (4.4%). However, even within Guayas, the illiteracy rate was significantly higher in rural areas (13.7%) compared to urban areas (3.3%). Rurality is one of the most notable causes of educational inequality (e.g., Delprato and Frola, 2022) and is associated with higher levels of poverty and deprivation of rights, including limited access to education (García-Quero and Guardiola, 2018; Santos and Villatoro, 2018). In 2020, the illiteracy rate in Ecuador was 3.8% in urban areas compared to 12.3% in rural areas (CNII, 2023). This disparity highlights the impact of rurality on educational outcomes.

Sixth, although its influence remained minimal in 2021, our findings indicate that spatial inequality expanded from 2014 to 2021, driven by increasing disparities across regions. The rise in spatial inequality in Ecuador may be attributed to the already mentioned decentralisation process. The result is consistent with the observation that, at the subnational level, decentralisation tends to favour more developed territories, leading to greater benefits for these regions and, consequently, increasing spatial inequalities (Kameshwara et al., 2020; Xiang et al., 2020). Despite the growth in spatial inequality, its almost negligible impact on total educational inequality prevented an overall increase, which, as mentioned before, actually declined during the study period. It is worth noting, however, that a proportion above 6% is a cautious threshold for designating a high level of spatial inequality (Novotný, 2007; Paredes et al., 2014). With a value close to this threshold in 2021 (5.4%), our results indicate the existence of a non-negligible spatial inequality, which, as Kanbur (2006) points out, should not be disregarded.

Lastly, our findings are in accordance with the latest official educational statistics of Ecuador and reflect the socioeconomic and demographic characteristics of its provinces. Thus, Pichincha, Guayas, El Oro and Galápagos displayed the highest educational averages and the smallest individual differences in our study and the official statistics show that their illiteracy rates were among the lowest in the country in 2020: 5.7, 4.4, 2.4 and 1.6%, respectively, compared to the national figure of 6.4% (CNII, 2023). Pichincha, with one of the best improvements during the study years had the highest percentage of the population completing university education in 2020 (17.2% compared to 11.7% nationally) (CNII, 2023). Moreover, the provincial governments

of Pichincha and Guayas implement notable educational programmes, such as free textbooks. Additionally, our results show that Pichincha and Guayas had the greatest impact on Ecuadorian intra-provincial educational inequality in both study years, consistent with literature indicating their major contribution to inequality in 2006 and 2014 (Guijarro-Garvi et al., 2022). Our findings are also in accordance with those obtained by Canelos Salazar et al. (2020) in an analysis of the socioeconomic development of Ecuadorian cities, which includes the educational dimension, showing that Guayaquil (Guayas) and Quito (Pichincha) are among the cities with the highest levels of development in the country. Galápagos, another top-performing province in our analysis, attracted mainland Ecuadorians and international researchers, leading to the highest non-University Higher Education attendance rate in the country in 2020 (97.6% compared to 71.3% nationally) (CNII, 2023).

On the contrary, Bolívar and Chimborazo, marked by poor educational performance and significant intra-provincial inequality in both study years, faced high illiteracy rates in 2020 (17.9 and 20.6%, respectively) (CNII, 2023). These provinces have a large percentage of indigenous population (25.4 and 38.0%, respectively) (INEC, 2010). Official data show that the Ecuadorian indigenous population had the highest illiteracy rate in the country in 2020 (16.1% compared to 2.8 and 4.7% for the white and the mestizo population, respectively) (CNII, 2023). Challenges faced by indigenous populations, including educational disadvantage, are compounded by high unemployment and poor health (Hanemann, 2005). Moreover, the majority of inhabitants in these provinces reside in rural areas (67.5% in Bolívar and 57.3% in Chimborazo in 2021) (INEC, 2022b), which is often associated with lower levels of education, as mentioned before. Our results are in accordance with those by Candia et al. (2015) for Ecuadorian provinces, based on the development of a subnational development indicator in LAC that includes the educational dimension.

Additionally, most Amazonian provinces, despite being among the poorest in Ecuador (Álvarez-Gamboa et al., 2021; CNII, 2023), achieved good educational outcomes and were among the twelve least unequal in both study years. This may be influenced by increasing immigration to the region, where the migrating population tends to have better education levels (Grey and Bilsborrow, 2020; Davis et al., 2017). The establishment of a national network of intercultural bilingual schools by MOSEIB may also contribute to their success, providing education for the indigenous population, particularly in the Amazonía region, which has the highest number of such schools in Ecuador (*Instituto Nacional de Evaluación Educativa* [National Institute for Educational Evaluation], 2018). Our results align with the fact that attendance rates for general basic education in all Amazonian provinces in 2020 exceeded the national average (CNII, 2023).

Our findings for the Ecuadorian provinces also align with studies examining the influence of neighbourhood effects on educational outcomes, which demonstrate that residing in disadvantaged areas tends to result in lower educational attainment, and vice versa (e.g. Otero et al., 2023 or Troost et al., 2023).

Limitations of the study and future research. The reliability of our findings depends on the survey's accuracy, constituting the primary limitation due to data scarcity. Firstly, the absence of cantonal-level coverage limits insights into the within provinces component. This data gap hinders understanding the impact of territorial divisions. Additionally, a longer study period might reveal greater differences, potentially influenced by the 2006 Ten-Year Education Plan. However, we chose not to extend the analysis before 2014, ensuring inclusion of Galápagos and Amazonian provinces. In this sense, our comprehensive examination of all Ecuadorian provinces and regions provides a thorough spatial perspective on territorial inequality and the role of geographic location. Nevertheless, the absence of a recent population census prevents comparing migration data for Amazonía and Galápagos, potentially influencing the observed results. It should be note that, despite the brief study period, outcomes highlight overall improvements in educational attainment across Ecuadorian provinces. Exploring the educational differences based on residence in rural or urban areas could offer additional insights into Ecuadorian educational inequality, complementing the information provided by this study on spatial inequality's role.

There is concern that without intervention policies, the COVID-19 pandemic's repercussions could significantly affect future student generations. In LAC countries, the pandemic caused the longest global interruption of face-to-face classes (ECLAC, 2022). Not all students had access to necessary technological tools and connectivity during this period (UNDP, 2021). In Ecuador, students in remote rural areas lacked technology or internet access, and over half of non-university students did not engage in e-learning during lockdowns (Hohenthal and Minoia, 2021). Prolonged school closures led to increased dropout rates and substantial learning setbacks (Busso and Messina, 2020). This situation reduced learning opportunities and affected the socio-emotional well-being of students (ECLAC, 2022), exacerbating educational inequalities. Implementing our suggested methodology in future research would help assess the prospective impact of the COVID-19 pandemic on educational inequality in Ecuador.

Data availability

The present study utilized microdata from Ecuador's National Survey of Employment, Unemployment, and Underemployment for the years 2014 and 2021. These datasets are freely available at the following links: https://www.ecuadorencifras.gob.ec/enemdu-2014 and https://www.ecuadorencifras.gob.ec/enemdu-2021/. The databases employed in this research were derived from the microdata and have been uploaded as supplementary information.

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Notes

1 For a detailed analysis of the methodological aspects related to inequality decompositions, see Shorrocks (1980) and Shorrocks and Wan (2005).
2 This programme, a unique pilot project spanning six years, evaluated the performance of 15-year-old students (Grade 7 or above) in three key areas: Reading, Mathematics and Science. Ecuador achieved an average score of 409 in Reading, 377 in Mathematics, and 399 in Science, surpassing the scores of other participating countries – Guatemala, Honduras and Paraguay in LAC, Bhutan and Cambodia in Asia and Senegal and Zambia in Africa – according to the Organisation for Economic Co-operation and Development [OECD] (2018a). However, Ecuador's scores fell notably below the OECD averages from PISA 2015 (493, 490 and 493, respectively) (OECD, 2015; OECD, 2018a).
3 Analysis conducted for the economic dimension of well-being.
4 The ideology of life that underlies the *Buen Vivir* (*Sumak Kawsay* in *Kichwa*) is based on balance with the earth, the community and the environment (Domínguez et al., 2017; Shebell and Moser, 2019).
5 Percentage of population aged 5-14 years old who engaged in some economic activity for pay or profit during the reference week (INEC, 2022a).
6 Since 1990, Ecuador's political-administrative division has undergone several changes. The most significant change has been the creation of three new provinces: Orellana in the Amazonia region, in 1998, from the division of the province of Napo;

Santo Domingo de los Tsáchilas, in 2007, and Santa Elena, in 2008 (*Ministerio Coordinador de Desarrollo Social* [Ministry for Social Development], 2019).

7 In the case of non-university education, we considered the *Ley Orgánica de Educación* (Education Act) in 1983 and the *Ley Orgánica de Educación Intercultural Bilingüe* (LOEI, or Intercultural Bilingual Education Act), in 2011, amended in 2021. Meanwhile, for university education, the *Leyes Orgánicas de Educación Superior* (LOES, or Higher Education Acts) in 2000 and 2010, as well as the *Ley Orgánica Reformatoria a la Ley Orgánica de Educación Superior* (Reform Act) in 2018, were considered.

8 Dispersion and inequality are two concepts that are often used interchangeably in relation to the variability of a distribution. In fact, measures of dispersion are potential measures of inequality (Gasparini et al., 2012) and can even be considered as such (see Bourguignon [1979] or Shorrocks [1982], and more recently Permanyer and Scholl [2019] or Villar [2017]). However, some measures of dispersion do not satisfy the desirable properties of a measure of inequality (independence of scale and population size or Pigou-Dalton transfer principle). The coefficient of variation is a dispersion measure that satisfies these properties, but it is not additively decomposable. Therefore, in this paper we use the half of the square of the coefficient of variation, since this inequality measure is cardinally equivalent to the coefficient of variation (linear transformation) and, in addition to satisfying the above properties, it is additively decomposable.

9 In a one-stage inequality decompositions, total inequality can be expressed as the sum of two components: the between-group and the within-group component (Shorrocks, 1980). The interpretation of these components depends on the type of disaggregation performed. For instance, if the disaggregation is territory/individual (meaning individuals are grouped by territories), the within-group component, or individual inequality, measures the inequality existing among individuals within each territory and is a weighted sum of the inequality of each territory. The between-group component, or spatial inequality (Novotný, 2007), measures the inequality between territories and is obtained by comparing the mean educational values of individuals in each territory.

10 The results shown in Fig. 1 are consistent with the values of the central tendency measures of the 'years of schooling' distribution in Table 2. Thus, distributions skewed to the right had a provincial mean greater than the median, which, in turn, is greater than the mode. In contrast, when the distribution was skewed to the left, the mode was the highest value of these three descriptive statistics, while the mean was the lowest.

11 The illiteracy rate is the percentage of people in a reference age group –generally 15 years and over– who cannot read and/or write, calculated over the total number of people in that group (*Instituto Nacional de Estadística y Censos* [INEC, or National Department of Statistics and Census], 2014). As with the years of education variable, the illiteracy rate in 2020 does not capture the effects of the COVID pandemic.

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MG-G: conceptualisation, methodology, formal analysis, investigation, data curation, writing original draft, writing, review and editing, visualisation and supervision. BM-E: conceptualisation, investigation, writing original draft, writing, review and editing, and supervision. PBM-P: data curation, visualisation, and writing original draft. YTC-M: data curation, writing original draft, and review and editing.

Competing interests

The authors declare no competing interests.

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