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# Regional Disparities in Literacy and Numeracy Skills Among Romanian Adults: Evidence From e-PASS 2023

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## ABSTRACT

This article investigates regional disparities in Romanian adults' numeracy and literacy skills. We analyse a novel data set that combines the assessment of numeracy and literacy competencies of the adult population in Romania with information about regional economic conditions and educational administrative data. Using a background questionnaire and a cognitive test following e-PASS methodology and tools (everyday-life Practices and Skills Survey), the study is one of the first to assess the key skills of the Romanian adult population. The e-PASS survey is based on the Literacy Assessment and Monitoring Programme (LAMP), developed by the UNESCO Institute for Statistics (UIS), and corresponds to PIAAC levels 1 and below 1. The findings indicate that individuals performing better at literacy and numeracy assessments have higher levels of education, are part of younger generations, and live in urban areas and economically developed Romania's regions. The results of this study provide a detailed picture of the current situation and can serve as a benchmark against which to compare current results in the region or future longitudinal findings.

## 1 | Introduction

According to OECD (2013), competency is the capacity to use one's tools, knowledge, and techniques in a social context to reach specific goals. Competencies are opposed to a body of knowledge and set of techniques and refer to using knowledge and skills in everyday life and different contexts. However, competencies and skills are widely used interchangeably. Competency is frequently defined as using knowledge and skills (Rychen and Salganik 2003; European Commission 2007; OECD 2013).

Literacy and numeracy are key competencies for effective participation in the modern world, influencing individuals' ability to engage with the labour market, pursue further education, and navigate daily life (Hanushek et al. 2015; Hanushek and Woessmann 2019; Tout 2020). Based on OECD (2014), literacy is

defined as 'understanding, evaluating, using and engaging with written texts to participate in society, to achieve one's goals, and to develop one's knowledge and potential' while numeracy is defined as the 'ability to access, use, interpret and communicate mathematical information and ideas in order to engage in and manage the mathematical demands of a range of situations in adult life'. Most studies focused on the demographic transition towards an ageing population, coupled with the swift advancements in technology within developed countries, highlighting the imperative for individuals to persistently develop their skills (such as data analysis, inter-cultural communication, coding, or interpreting technical information) across their lifespan. To enhance these abilities throughout their lives, literacy and numeracy serve as foundational pillars for lifelong learning (Durda et al. 2020; Wicht, Reder, and Lechner 2021; Wolf and Jenkins 2014).

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Reports from OECD (2013, 2016) emphasise significant regional differences in competencies performance among developed and developing countries. In the case of Romania, a developing European country (IMF 2024). Performance in the Programme for International Student Assessment (PISA) has seen variations over the years, registering scores below the European average. Romania has seen minimal focus on teaching standardised literacy and numeracy, with restrained research assessing the predictors of adult's performance in numeracy and literacy standardised tests. There are many reasons for this lack of focus: little agreement on what constitutes literacy and numeracy; poor professional development in literacy and numeracy; limited understanding of how adults with diverse characteristics, needs and backgrounds obtain literacy skills; and the lack of alignment among content standards, curricula and instruction, without forgetting assessments (ROMANIA REPORT 2024). However, as a candidate country for OECD, Romania is committed to participate in the next Programme for the International Assessment of Adult Competencies (PIAAC) assessment. This paper presents the novel results of the first national assessment of the Romanian's levels of numeracy and literacy scored at a standardised test. The test used was e-PASS, a survey developed by UNESCO based on LAMP and MiniLAMP following similar principles as PIAAC.

The remainder of this article is structured as follows. Section 2 presents the recent findings on adults' numeracy and literacy skills with a focus on regional disparities and socio-demographic differences. Section 3 presents the data employed in the analysis, while Section 4 discusses the empirical strategy employed in the analysis. In Section 5, we present the findings and in Section 6, the discussions and conclusions.

## 2 | Related Literature

The growing effort in enhancing the provision of fundamental literacy and numeracy education for adults is a fundamental pillar to equip them with the knowledge and abilities necessary to adapt to the continuously increasing expectations of the labour market.

An increasing number of studies explore what influences the cognitive performance of adults (Lechner et al. 2021; Tout 2020; Yalcin 2019). On one hand, individuals' performance in standardised tests is influenced by socio—economic factors, such as social class, and inherent characteristics like gender, race and ethnicity (Rodríguez-Hernández, Cascallar, and Kyndt 2020). Socio-economic status is seen as the primary factor, as disparities in individuals' performance across racial, ethnic, familial and educational backgrounds are believed to be largely attributable to it. This view is implicitly adopted by policymakers who attribute poor student outcomes to socio-economic and demographic issues, advocating for increased support to underprivileged families or their schools.

On the other hand, the performance of individuals can be influenced by external factors such as regional disparities (Daniele 2021; Stanef and Manole 2013; Zarifa, Seward, and Milian 2019). The disparities in these competencies, particularly

how they correlate with socio-demographic characteristics and regional variations, represent an ongoing debate within the realm of educational research (Daniele 2021; Støren, Lundetræ, and Børing 2018; Zarifa, Seward, and Milian 2019). However, more needs to be known about the gap between individuals' performance at standardised tests and socio-demographic characteristics and regional disparities in developing countries, to be able to identify to most appropriate solutions and intervention programme.

This article extends the previous literature by testing, in a comparative perspective, common patterns and differences between NUTS-2 regions of Romania (Nomenclature of Territorial Units for Statistics), which have not been previously compared in an educational study using empirical data. More specifically, the article delves into comparing adult numeracy and literacy performance based on several individual socio-demographic indicators, as well as based on the prevalent educational disparities observed between regions (Cismaru and Corbu 2019; Stanef and Manole 2013). It also aligns with an international stream of research focused on investigating the individual and regional factors behind the differences in performance among adults for numeracy and literacy standardised test across different regions within countries (Andreola et al. 2021; Bratti, Checchi, and Filippin 2007; Daniele 2021; Desjardins and Warnke 2012; Lechner et al. 2021; Støren, Lundetræ, and Børing 2018).

### 2.1 | Numeracy and Literacy Performance Under the Lens of Age Differences and Education Attainment

In all countries participating in the PIAAC, there is a noticeable improvement in performance with age, peaking at around 30years, followed by a gradual decline. However, it is important to note that the extent of performance variation between the youngest and oldest age groups significantly differs from country to country (OECD 2013). According to the latest OECD (2024) report, in the vast majority of countries and economies, adults aged 55–65 display the lowest average proficiency in all domains. The exceptions are New Zealand and Sweden, where the lowest average proficiency has been reported in younger groups.

Therefore, extended research on skill development in adulthood agrees on the lifelong adaptability of skills. However, they differ in their views on the timing, individuals affected, and whether changes constitute gains or losses. Cattell (1971) differentiated between fluid intelligence (Gf), which declines after early adulthood and crystallised intelligence (Gc), which grows with experience and education throughout adulthood, only declining in late age (Cattell 1971). This framework was supported and refined by later research, by Baltes's (1993) distinction between cognitive mechanics (similar to Gf) and cognitive pragmatics (similar to Gc). This suggests that literacy and numeracy skills, akin to Gc, are acquired through education and practice, suggesting they may remain stable or improve over adulthood until very old age (Lechner et al. 2021). Furthermore, Practice Engagement Theory (PET) adds that engagement in literacy and numeracy activities can lead to skill changes over time. This core principle of PET aligns with the theories of Cattell and Baltes, yet it goes further by emphasising the variations in skill development

among individuals (Reder, Gauly, and Lechner 2020). From a more sociological perspective, the Matthew effect hypothesis suggests that initial skill levels can predict further skill development, influenced by education and job complexity (Blossfeld and von Maurice 2011). Drawing on extant studies (Ritchie and Bates 2013), there is evidence that literacy and numeracy skills gained in early life have a substantial positive association with intelligence scores, academic motivation and duration of education.

More recent research shows that literacy and numeracy skills evolve throughout adulthood, supporting theories of lifelong skill adaptability, the influence of life stages on skill development and individual variances in skill progression (Desjardins and Warnke 2012; Paccagnella 2016). Studies confirm that literacy and numeracy are not fixed post-childhood; instead, they change over the lifespan, influenced by both genetic factors and ongoing learning (Andreola et al. 2021; Desjardins and Warnke 2012; OECD 2016; Paccagnella 2016).

As studies using longitudinal data from PIAAC show, skill levels typically follow an inverted U-shape across the age spectrum, peaking around 30 years old before gradually declining (OECD 2016; Paccagnella 2016; Podolskiy and Popov 2014).

However, this study follows the line of rationale emphasised by Salthouse (2010), arguing that cognitive abilities, including memory, problem-solving and attention, tend to decline with age (Salthouse 2010, 2019), which in turn impacts numeracy and literacy skills. As these essential cognitive faculties diminish over time, older adults may find it increasingly challenging to perform tasks that necessitate such skills, contrasting sharply with the proficiency observed in younger counterparts (Park et al. 2002; Salthouse 2010). Consequently, we anticipate that numeracy and literacy scores will have a negative correlation with age, indicating a decline rather than a cumulative effect over time. Drawing from the extensive body of research on skill development and incorporating data relevant to the local context, we hypothesize that:

**Hypothesis 1.** *Younger generations in Romania tend to perform better in literacy and numeracy scores compared to older generations.*

Beyond general age trends, education variations in skill development are also emphasised by some studies. For instance, Paccagnella (2016) utilised PIAAC 2012 data to reveal that adults with higher education levels showed more significant skill declines with age compared to those with lower education levels. Furthermore, longitudinal research indicates that higher education may actually guard against literacy declines over time (Wicht, Rammstedt, and Lechner 2020). A study across six European countries demonstrated that extended compulsory schooling notably enhances cognitive performance even four decades later, suggesting durable benefits of more education (Schneeweis, Skirbekk, and Winter-Ebmer 2014). Similarly, studies found that smaller class sizes and higher quality teaching in early education lead to better college attendance, higher earnings, and more completed education later in life (Fredriksson, Öckert, and Oosterbeek 2013). Research on mathematically talented adolescents showed that early exposure

to advanced STEM education correlates with greater achievements in STEM fields as adults (Wai et al. 2010). Furthermore, in his work, Flynn (2007) developed the concept ‘Flynn effect’ because he observed a rise in average intelligence scores across populations over generations, often measured by tracking performance changes over time in specific age groups, like those of 18-year-olds. Factors like increased schooling are considered significant contributors to the Flynn effect. Research also demonstrates the predictive power of adolescent literacy scores on future educational and occupational success, highlighting the importance of early education levels in determining later life outcomes (Cort and Larson 2015). In line with the literature, we hypothesize that:

**Hypothesis 2.** *In Romania, higher levels of education increase the chance of performing better in numeracy and literacy tests.*

In terms of gender differences in literacy and numeracy skills, the findings have been mixed, with some studies noting women’s strengths in literacy and men’s in numeracy, while others found minimal to no gender disparities (Solheim and Lundetræ 2018). The impact of gender on skill change over time remains debated, with some research showing no clear gender differences (OECD 2016; Reder, Gauly, and Lechner 2020; Wicht, Rammstedt, and Lechner 2020), and others indicating women begin with higher literacy levels but make smaller gains than men over time (Wolf and Jenkins 2014). Considering the mixed results in terms of gender’s impact on numeracy and literacy scores, this paper uses gender as a control variable.

## 2.2 | Urban—Rural Divides and Regional Disparities Affect Performance in Numeracy and Literacy Assessments

The disparity in literacy and numeracy performance between urban and rural populations has garnered significant attention in educational research (Brasington 2002; Drescher et al. 2022; Jakubowski, Hippe, and Araújo 2018; Rodríguez-Pose and Tselios 2011; Buck, Chinn, and Upadhyay 2023).

Such disparities contribute to widening socio-economic gaps, influencing individuals’ abilities to participate fully in society and the labour market. Urban–rural divides significantly influence educational outcomes, with adults in rural areas often performing less well on literacy and numeracy assessments compared to their urban counterparts. Jakubowski, Hippe, and Araújo (2018) highlight that rural areas frequently lack access to quality educational facilities and experienced educators, contributing to lower performance levels. Furthermore, socio-economic factors prevalent in rural areas, such as higher poverty rates and lower parental education levels, also play a critical role (Schafft and Jackson 2010). Additionally, the OECD’s PIAAC has consistently found that adults in urban areas outperform those in rural areas in literacy and numeracy skills (OECD 2013). Therefore, we conjuncture that:

**Hypothesis 3.** *Individuals living in urban areas of Romania tend to perform better in literacy and numeracy scores compared to individuals living in rural areas.*

Regional disparities extend beyond the urban–rural dichotomy, affecting adults' performance in literacy and numeracy assessments (Agasisti and Cordero-Ferrera 2013; Daniele 2021; Jakubowski, Hippe, and Araújo 2018; Stanef and Manole 2013; Zarifa, Seward, and Milian 2019). Research by Daniele (2021) demonstrates that economic disparities between regions can lead to unequal educational outcomes. Regions with higher unemployment rates and lower average incomes tend to invest less in education, resulting in lower performance in literacy and numeracy assessments among adults (Chetty et al. 2014). International comparisons, such as those provided by PIAAC, have also shed light on how disparities between regions within countries can be as significant as differences between countries themselves. For instance, studies found that within-country variations in educational outcomes could be attributed to differences in educational policies, the quality of education provided, and the socio-economic background of the learners (Agasisti and Cordero-Ferrera 2013).

The socio-economic status of individuals and their access to quality education emerge as critical factors in explaining performance disparities in literacy and numeracy assessments. According to Hanushek and Woessmann (2012), the quality of education, including the availability of skilled teachers and resources, significantly impacts adults' literacy and numeracy skills (Cismaru and Corbu 2019; Hanushek and Woessmann 2012, 2019; Ivan et al. 2012). Moreover, adults from lower socio-economic backgrounds often have limited access to continuing education and skill development opportunities, exacerbating disparities (Hanushek and Woessmann 2019). Research also emphasises the importance of lifelong learning and adult education programme in mitigating these disparities (Krupar, Horvatek, and Byun 2017). Such programme can provide adults, especially those from disadvantaged backgrounds, with opportunities to improve their literacy and numeracy skills, thereby enhancing their employability and socio-economic status. The regional disparities in Romania are significant in terms of economic development (Diaconu 2015), and it is precisely because of these variations that we anticipate substantial differences in numeracy and literacy scores across different Romanian regions. In this context, we formulate an exploratory research question:

RQ1. How do regional disparities within Romania influence individuals' performance to literacy and numeracy tests?

Thus, the aim of this paper is threefold. First, to assess the differences between several socio-demographic characteristics and numeracy and literacy performance in a developing country. Secondly, to explore if numeracy and literacy performance varies between Romanian regions. There are important studies focusing on analysing the performance of skills as influenced by socio-demographic characteristics within Italian and Spanish populations, known for exhibiting significant differences among populations (Daniele 2021; Pensiero and Green 2018), or the effects of regional disparities or disparities between native and foreign-born adults in western countries in terms of numeracy and literacy performance (Levels, Dronkers, and Jencks 2017; Zarifa, Seward, and Milian 2019). There is limited evidence on how to use data on regional disparities' role in numeracy and literacy levels in developing countries. Thirdly, previous studies on Romania that explore regional disparities in education have

focused solely on the educational system and aggregate indicators, which may impact each region's school performance differently (Cismaru and Corbu 2019; Stanef and Manole 2013), and less on individual survey data (Ivan et al. 2012). This paper seeks to bridge this gap in the literature by conducting a spatial and multilevel analysis of the Romanian population's performance on standardised tests in numeracy and literacy. To the best of our knowledge, this study is the first in Romania to assess the numeracy and literacy performance.

### 3 | Description of the Dataset and Variables

#### 3.1 | Data Set of EduCAd Project

To test our hypotheses and research question, we rely on the individual data from the 2023 wave of the EduCAd project of the Romania Ministry of Education (ME), in partnership with the National University of Political Studies and Public Administration (SNSPA). The tools used in this research are the two standardised instruments employed by UNESCO Institute for Lifelong Learning through the e-PASS (everyday-life Practices and Skills Survey) and calibrated according to the Romanian context following their application during the pre-testing study ( $N=2041$ ). The instruments adapted from e-PASS to conduct the study were the background questionnaire and the cognitive test (e-PASS). The survey has collected information from individuals and contains representative data from all eight Romanian regions, as well as all 41 Romania counties. The dataset includes a sample of 4087 individuals, aged 15 and over<sup>1</sup>.

The main socio-demographic characteristics collected refer to age, gender, level of education and residential environment of the respondents, as well as participating in some non-formal education programme. Thus, the representative distribution according to the eight NUTS-2 regions of Romania (INS 2020) indicates that 17% of the respondents live in the North-East region, 9% of the interviewees live in the West development region, 10% in the South-West, 12% of the respondents reside in the Bucharest-Ilfov, Center, and South-East regions, and another 13% in the North- West, and another 15% in Sud-Muntenia. Regarding the urban–rural distribution, 6 out of 10 participants live in rural areas (57%), while the rest (43%) live in urban areas. The average age of the respondents is 48.8 years, and the gender distribution is 51% male and 49% female (see Tables A1 and A2 in the Appendix for detailed descriptive statistics and variables' measurement).

#### 3.2 | Measurements

##### 3.2.1 | Dependent Variables

To examine skills gaps across different socio-demographic characteristics of the Romanian population and across the 8 NUTS-2 regions of Romania, we extracted from the EduCAd dataset two key dependent variables: (1) Literacy ( $M=228.13$   $SD=64.10$ ) and (2) Numeracy ( $M=247.99$ ,  $SD=144.39$ ).

The independent variables were computed based on the e-PASS test (UNESCO) mentioned above. The e-PASS assesses the skills

of the population aged 15 and over. This test consists of 15 questions, of which 5 measure literacy skills (basic text understanding and interpretation) and 10 measure numeracy skills (basic mathematical calculation competencies). The scoring system for each test item is encoded as follows: 0 = missing response, 1 = correct response, 7 = incorrect response and 9 = could not be administered. To generate standardised scores based on the responses we used a tool created by UNESCO, specifically for this purpose<sup>2</sup>. The tool is flexible and simple, and it generates basic output on literacy and numeracy skills and prepares the data for further analysis. It provides by default the standardised scores (the theoretical range of scores obtained in this test is [0; 800], where 800 represents the maximum score). The tool also provided 10 dichotomous-scale plausible values indicating whether the respondent is above (1) or below (0) the Minimum Literacy (or Numeracy) Level threshold (<226 points). However, given the design of e-PASS, we can also build the plausible values for PIAAC level 1 (176–226 points) and below level 1 of proficiency (<176 points).

### 3.2.2 | Independent and Control Variables

In the analysis, we employed two levels of variables: individual—level (1) and regional-level (level 2).

First, since our primary goal of the analysis is to determine if socio-demographic characteristics influence the cognitive skills of individuals, we select age, education level and residency as our key independent variables. The respondents' age was kept as a continuous variable. Respondents' educational attainment was also measured as a continuous variable (number of years spent in education). Residency and gender were measured as dichotomous variables, where 1 means urban 0 means rural, and 1 means male and 0 means female respectively. The basic assumption would be that respondents who have higher levels of education, who live in urban areas, and who are part of younger generations tend to perform better at numeracy and literacy assessments. Furthermore, we also used as an independent variable the respondent's region of residence at the time of the interview. We used a categorical variable accounting for the eight NUTS-2 regions of Romania: (1) North—East, (2) South—East, (3) South Muntenia, (4) South—West, (5) West, (6) North—West, (7) Center, (8) Bucharest—Ilfov. The omitted (reference) category in regressions is Bucharest—Ilfov. For the robustness models, the variables were recoded into individual dummy variables (see Appendix for descriptive statistics and Supporting Information for robustness models). To reduce the risk of omitted variable bias, all our models control for several factors: gender, residency and enrollment in a non-formal education program in the last 12 months.

Second, to explore if there are regional differences in numeracy and literacy scores, beyond the individual—level variable measuring the region, we also extracted some regional—level variables. The source of data is twofold: part of the variables come from the Eurostat database, while another important source was the Romanian National Institute of Statistics (INS). The main important regional regressor of interest was the GDP growth rate (Eurostat code: nama\_10r\_2gdp; 2012–2022). This indicator is used as a proxy for regional wealth. Further

regional regressors are the unemployment rate (Eurostat code: lfst\_r\_lfu3rt; 2012–2022), and employment rate (INS Tempo code: FOM103D; 2012–2022) at the regional level. The regional economic indicators were determined by calculating the annual growth rates and then computing the average of these rates for the period from 2012 to 2022.

In terms of regional education characteristics, the teachers-per-student ratio was computed (INS Tempo code: SCL103E and SCL103E; 2012–2022) at the regional level. The teacher-student ratio was derived by first calculating the annual rates of teachers and students in each region between 2012 and 2022. These rates were then averaged, and the final ratio was obtained by comparing the average rate of teachers to the average rate of students.

## 4 | Methods

### 4.1 | Descriptive Analysis

First, we performed a descriptive analysis of the data, as well as a comparative analysis of literacy and numeracy skills across various demographic subgroups. Thus, we tested the association between the level of numeracy and literacy competencies with gender (male, female), age (15–34, 35–49, 50–64, 65+), level of formal education (maximum gymnasium, professional/ high school, tertiary studies), residence environment (urban, rural) and participation or not in non-formal education programme in the last 12 months. All these characteristics represent potential factors that could contribute to the achievement of a lower or higher degree of cognitive skills. Furthermore, in order to emphasise the regional differences in competencies of Romanian adults, we performed several spatial analyses of economic indicators of the regions, as well as average regional numeracy and literacy scores.

### 4.2 | Hierarchical Linear Modelling (HLM)

Second, given the hierarchical nature of data, where individuals are grouped into counties, and counties are further grouped into regions, a multilevel analytical approach is employed to explore the effects of individual characteristics and regional factors on performance. This approach is necessary to adequately address the hierarchical organisation of the data, as detailed in Goldstein (1995) regarding multilevel models. Multilevel models are essential in this context because they account for correlated errors and offer more robust and conservative statistical analysis. The study employs Hierarchical Linear Modelling (HLM) to examine performance across various levels (such as individual, county and regional levels) while managing the variability between these levels.

Specifically, we follow a two-level approach in order to consider not only differences among individuals but also among regions. We estimated three types of models for each of literacy and numeracy score outcomes, case in which we use the dependent variables as continuous. In the first model for each type of competence, we included respondents of all ages, while in the second and third models, we excluded the respondents with ages

between 15–18 and 15–23 years respectively (as they are most probably still in formal education).

## 5 | Findings

### 5.1 | Descriptive Results and Spatial Analysis

The descriptive analysis of the data facilitated the creation of a general profile of the socio-demographic characteristics of the surveyed population (see Tables 1 and 2 below). Special attention is given to the population that is below level 1 of key competencies. This category is considered the most vulnerable in terms of the minimal literacy and numeracy skills needed for everyday activities.

The distribution of competency levels within the sampled population is similar for the two key competencies. Below the minimum threshold (below level 1), 20% of the population falls with regard to literacy, and 28% with regard to numeracy. Level 1 is achieved by 17% of the population for literacy, while for numeracy, this percentage is 11%. Over 60% of the population is at level 2 (the highest) for both types of competencies (see Figures S1 and S2 in the Supporting Information).

Furthermore, the spatial analysis reveals some possible explanations for our research question investigating the regional disparities regarding the numeracy and literacy performance of Romania's population. The maps in Figures 1 and 2 suggest that individuals in the South-East, South-Muntenia and North-West perform significantly better than those in the North-East, South-West and West. Interestingly, the patterns of literacy and numeracy do not perfectly overlap, suggesting that the factors influencing these skills may differ even within the same region.

For instance, the West region has higher literacy scores than North-East, however, the same pattern is not applied to numeracy scores, with the West region performing worse than North-East in numeracy assessments. A possible explanation for this may be the lack of emphasis on mathematics education or a shortage of qualified mathematics teachers.

### 5.2 | Results of Multilevel Models

Hypotheses 1, 2 and 3, as well as our RQ1 were tested using multilevel regression analysis (Table 3)<sup>3</sup>. The analysis focused on various predictors, including enrollment in a non-formal education program in the last 12 months, age, residency, gender, and years spent in education, while accounting for random effects associated with different regions and counties in Romania.

The fixed effects in our models support H1 and H2, as well as H3: the years spent in education, age, and living in urban areas are significant predictors across all models. Individuals who spend more time in education tend to perform better in numeracy and literacy assessments, underscoring the critical role of education in cognitive development and skill acquisition.

This finding aligns with the existing literature, emphasising the importance of educational attainment in enhancing numeracy and literacy skills (Daniele 2021; Gustafsson 2016). In contrast, age demonstrates a negative relationship with these skills: younger individuals have more chances to obtain higher scores for numeracy and literacy. This trend persists across all models, albeit with varying degrees of impact. Notably, the influence of age diminishes when younger age groups (15–18 and 15–23 years) are excluded from the analysis (Table 3, Models 3–6). This variation suggests a potential generational effect on

TABLE 1 | Skills distribution by education level.

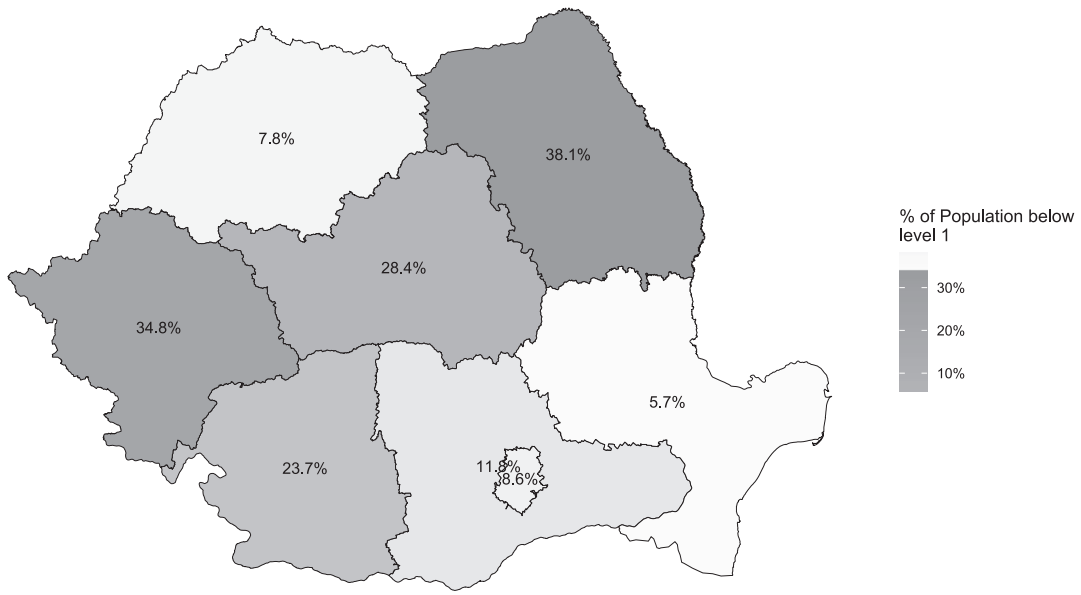
	Below level 1		Level 1		Level 2	
	Literacy	Numeracy	Literacy	Numeracy	Literacy	Numeracy
Maximum lower secondary education	43.45%	52.69%	17.85%	9.70%	37.70%	37.61%
Maximum post-secondary non-tertiary education	13.84%	21.05%	17.37%	11.19%	68.78%	67.76%
Tertiary education	6.50%	12.29%	15.48%	11.53%	78.02%	76.18%

Source: Authors' computations based on the EduCAD dataset 2023.

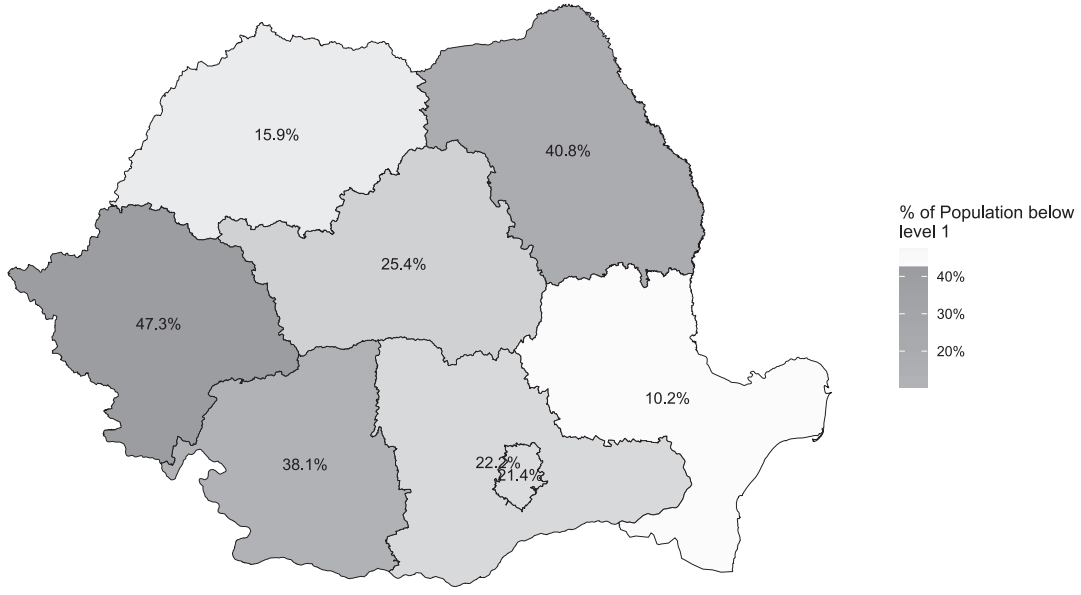
TABLE 2 | Skills distribution by age.

	Below level 1		Level 1		Level 2	
	Literacy	Numeracy	Literacy	Numeracy	Literacy	Numeracy
15–34 years	15.33%	20.23%	16.49%	8.59%	68.18%	71.19%
35–49 years	15.37%	22.83%	17.32%	12.17%	67.31%	65.00%
50–64 years	20.18%	25.53%	14.09%	10.11%	65.73%	64.36%
+65 years	30.57%	42.91%	20.29%	12.79%	49.14%	44.29%

Source: Authors' computations based on the EduCAD dataset 2023.



**FIGURE 1** | Percentage of the population with literacy scores below Level 1, by region. *Source:* Authors' computations based on the EduCAD dataset 2023.



**FIGURE 2** | Percentage of the population with numeracy scores below Level 1, by region. *Source:* Authors' computations based on the EduCAD dataset 2023.

numeracy and literacy skills, possibly reflecting changes in educational policies, pedagogical methods or cognitive ageing processes. In line with Park et al. (2002) and Salthouse (2010), this finding highlights that the evolution of literacy and numeracy skills over the course of adulthood follows a negative trajectory, with skills experiencing a gradual decline with age.

In terms of the random effects included in the models, the regional GDP growth rate exhibited a varied influence, showing a positive relationship with numeracy scores in some models (Models 1,3,5), yet its impact was more pronounced in literacy models (Models 2,4,6). This pattern implies that economic growth may affect numeracy and literacy skills differently, perhaps due to the distinct nature of these skills in economic contexts (Hanushek and Woessmann 2019). The general

unemployment rate did not present a consistent significant relationship with educational outcomes; however, the employment rate had a notable positive effect on numeracy scores in Models 1, 3 and 5, indicating that higher employment could correlate with enhanced numeracy skills. Surprisingly, the student-teacher ratio showed minimal impact, suggesting that this factor might not be as pivotal in influencing numeracy and literacy skills in this particular context. Additionally, our study revealed interesting variations when younger age groups were excluded from the models. These variations were particularly evident in the impact of certain predictors, like age, indicating that the effect of age on educational skills might differ across various age cohorts. The differing impacts could be attributed to changes in educational exposure or life experiences across generations, highlighting the complexity of how demographic

**TABLE 3** | Extended multilevel models of individuals' numeracy and literacy scores.

	Numeracy		Literacy		Numeracy		Literacy	
	All ages		Excluded 15–18 years		Excluded 15–23 years			
	(1)	(2)	(1)	(2)	(1)	(2)		
Non—formal education in the last 12 months	−8.05 (15.06)	−0.81 (2.57)	−8.16 (6.15)	−1.08 (2.68)	−13.45** (6.56)	−3.43 (2.87)		
Age	−1.01*** (0.12)	−0.27*** (0.05)	−0.83*** (0.13)	−0.20*** (0.06)	−0.82*** (0.14)	−0.19*** (0.06)		
Residency (Urban)	7.93* (4.27)	4.69** (1.86)	6.92 (4.37)	4.07** (1.90)	7.46* (4.48)	4.23** (1.96)		
Gender (male)	1.87 (4.04)	−0.86 (1.76)	2.16 (4.13)	−0.84 (1.80)	2.64 (4.24)	−0.29 (1.85)		
Years spent in education	7.72*** (0.47)	3.83*** (0.20)	8.17*** (0.48)	4.04*** (0.21)	8.31*** (0.50)	4.03*** (0.22)		
Regional GDP growth rate	36.04 (25.86)	15.07 (18.74)	36.33 (27.26)	15.49 (19.37)	37.76 (26.76)	16.14 (19.58)		
Regional unemployment rate	13.86 (14.31)	3.79 (10.36)	14.70 (15.09)	3.90 (10.70)	13.95 (14.94)	3.45 (10.91)		
Regional employment rate	55.90** (22.11)	14.50 (16.01)	57.22** (23.34)	15.62 (16.57)	57.52** (23.02)	16.02 (16.83)		
Teachers to students' ratio	7.16 (24.12)	−6.80 (17.48)	7.70 (25.39)	−6.087 (18.04)	6.27 (23.02)	−6.59 (18.24)		
Constant	191.56*** (15.06)	189.09*** (9.19)	175.37*** (16.01)	182.84*** (9.56)	172.99*** (16.56)	182.59*** (9.91)		
<i>Random effects</i>								
Between-region variance	940	505.4	16,303	534.9	1012	554.8		
Within-region variance	16,243	3089.2	1037	3089.1	16,234	3098.2		
% Between	5.47%	14.05%	5.98%	14.75%	5.86%	15.18%		
Observations	4087	4087	3924	3924	3698	3698		
Log Likelihood	−25,596.08	−22,135.83	−24,532.65	−21,251.97	−23,109.54	−20,030.03		
AIC	51,216.16	44,297.66	49,091.31	42,529.95	46,245.08	40,086.06		
BIC	51,291.95	44,379.76	49,172.88	42,611.52	46,325.88	40,166.86		

Note: Standard errors are presented in parentheses; \*, \*\* and \*\*\* denote statistical significance at the 10%, 5% and 1% confidence.

factors interact with educational skill development. As assumed for the RQ1, the random effects associated with regions reveal substantial variability, indicating important differences in baseline numeracy and literacy scores across these groups, likely attributable to unobserved or unmeasured factors. However, the % between-region variance in numeracy suggests that while regional characteristics matter, individual and other within-region factors play a larger role in determining numeracy outcomes. When comparing regional variances in numeracy and literacy models, the higher between-region variance observed in literacy models (Models 2, 4, 6) compared to numeracy (Models

1, 3, 5) indicates that literacy outcomes are more influenced by regional disparities.

The findings from the analysis not only corroborated both hypotheses but also provided empirical evidence that warrants further investigation of our research question. All our robustness checks follow a similar pattern: respondents with higher levels of education, coming from younger generations and coming from specific regions are more likely to perform better in numeracy and literacy assessments (see robustness check results in Figures S3 and Figure S4, as well as in Tables S1 and S2 from

Supporting Information). In sum, these findings suggest that the individuals' performance to numeracy and literacy tests are not solely dependent on individual factors such as age and education level, but also on regional factors (Stanef and Manole 2013). Therefore, the higher the regional disparities in one country, the higher the differences in competencies among residents (Stanef and Manole 2013).

## 6 | Discussion

This paper has provided several significant insights into how individuals across NUTS-2 regions perform on numeracy and literacy standardised tests (see Figures A1 and A2 in the Appendix). It aimed at enhancing our understanding of how socio-demographic factors and regional disparities affect individuals' performance on standardised tests in numeracy and literacy. The paper encompassed both variations within regions and between regions to determine if these associations persist after adjusting for regional GDP growth rate, employment rate and other teacher-student' ratio. To achieve this, the paper employed the 2023 data from Romania, marking the first assessment of the numeracy and literacy skills of individuals aged 15 and older. The findings of this paper reinforce those of previous studies (Agasisti and Cordero-Ferrera 2013; Jakubowski, Hippe, and Araújo 2018; Wicht, Rammstedt, and Lechner 2021; Zarifa, Seward, and Milian 2019) that identified the determinants contributing to the differences in numeracy and literacy levels among individuals.

As discussed, our analysis focused on identifying both individual and regional factors that could explain variations in numeracy and literacy performance among individuals.

To the level of the individual, we investigated the impact of education and age on individuals' performance on standardised tests. As noted, studies have shown that socio-economic status is considered the key determinant, as it largely explains performance disparities among students of different racial, ethnic, family and educational backgrounds (Dalmaijer et al. 2023; Sammons 1995; Van Ewijk and Slegers 2010). Although previous research has explored various socio-economic indicators, this paper is the first to comprehensively assess to a large scale the impact of both socio-economic and socio-demographic factors on the numeracy and literacy test performance of Romanian adults. Prior studies predominantly concentrated on the influence of socio-economic and regional disparities solely on student outcomes (Cismaru and Corbu 2019; Ivan et al. 2012; Stanef and Manole 2013).

In line with prior research, this study's findings confirm that the higher the level of education individuals have, the better they perform in numeracy and literacy tests (Paccagnella 2016; Wicht, Rammstedt, and Lechner 2021). As observed, there are some variations in the impact of education on literacy performance, compared to numeracy performance, the latter being more impacted by the level of formal education the individual achieved. This trend suggests that educational duration plays a crucial role in enhancing adult numeracy and literacy skills, and the strengthening of this relationship when younger cohorts are omitted indicates that the benefits of education may accumulate

over time, potentially reflecting the compounding advantages of lifelong learning and experience. These findings address one of the debates in educational research, that is if lifelong learning contributes to better skills (Krupar, Horvatek, and Byun 2017). Contrary to our expectations, when controlling the enrollment in a non-formal education program, we do not observe a significant positive impact of non-formal education on individuals' performance on standardised tests.

In relation to the possible association between age and individuals' performance on standardised tests, our findings suggest that older generations are significantly and negatively correlated with both types of competencies. This may be linked to the low rates of Romanian adults participating in lifelong learning programme. Based on Eurostat (2024) data, in Romania, the participation rate of adults in continuous learning forms is half of that recorded at the EU level. This finding is in line with the research evidences on age-related disparities in literacy and numeracy skills (Paccagnella 2016). Specifically, this evidence underscores the concepts of lifelong skill plasticity, the dependency of skill development on different life stages, and the variability in skill progression among individuals and subgroups. The progression of literacy and numeracy skills throughout adulthood is characterised by a constant negative trajectory over the course of life (Park et al. 2002; Salthouse 2019; Wicht, Rammstedt, and Lechner 2021). The difference in skill levels across ages is significant; for instance, older adults (aged 55–65) on average score about 30 points lower on the PIAAC literacy scale compared to younger cohorts across the surveyed country.

At the regional level, the findings indicate variations in individuals' performance on numeracy and literacy standardised tests, which can be attributed to distinctive characteristics inherent to each region. Aligning with Hanushek and Woessmann's (2020) observation of economic growth's differential impact on these skills, this study indicates a positive correlation between regional GDP growth rate and numeracy scores and a more pronounced impact on literacy scores. Additionally, the significant positive relationship between employment rates and numeracy skills highlights the potential of economic stability in enhancing educational outcomes. This supports the broader literature's emphasis on the importance of economic factors in education. In terms of variance, the higher between-region variance observed in literacy outcomes compared to numeracy suggests that literacy is more sensitive to regional characteristics, highlighting the need for targeted interventions to address these disparities.

This study may be a foundation for future adult learning policies, as it provides data that highlights the vulnerable and at-risk regions and insights into the underlying causes of low adult key competencies in Romania. It also sheds light on the high importance of lifelong learning for literacy and numeracy performance as, based on our findings, age has a role in the decline of skills. Following the recommendations of OECD (2017, 2021) and UNESCO Institute for Lifelong Learning (CONFINTEA VII Marrakech Framework for Action: harnessing the transformational power of adult learning and education, 2022) on adult learning policies, this paper makes the following key policy recommendations. First, based on current reports on adult skills assessments, we emphasise the need to establish a framework for governing adult learning in Romania by promoting a

multi-stakeholder approach that will facilitate the development of local intervention programme. Second, as shown in this study, adult learning programme should be developed by considering the local needs assessment and skills performance. To tackle the very low levels of key competencies in adults, it is necessary to establish adequately funded local learning intervention programme, ensure the quality of education through professional educators and trainers, and develop a learning infrastructure. Third, local authorities should be empowered to foster a learning culture for all by raising awareness of the importance of learning in everyday life and creating learning opportunities within local communities. Last but not least, drawing on our study and extant research, we assume that developing flexible adult learning opportunities by partnering with employers to encourage and facilitate learning for their workforce is necessary.

Before concluding, we highlight some limitations of the study which need to be acknowledged. First, there are inherent limitations of not using longitudinal data even coming for the challenge to observe how an individual's literacy and numeracy skills evolve over time. Therefore, it is difficult to observe and assess the lifelong learning process, including how individuals acquire new skills or lose unused ones, as well as to monitor the effects of educational programme or interventions on adult literacy and numeracy. Even though we face the absence of longitudinal data, the novelty of this large-scale dataset at the national level in Romania offers a unique opportunity. These results can serve as a foundational benchmark for future research. Second, we only measured individuals' education level and not also the education level of their parents, which could be a significant oversight. Parental education levels often play a crucial role in shaping the educational opportunities and outcomes of their children. This omission limits our ability to explore intergenerational influences on literacy and numeracy skills, potentially overlooking key socioeconomic and environmental factors that contribute to adult educational performance.

Despite these limitations, the study offers three primary findings. First, prolonged engagement in formal education is crucial for cognitive development and the acquisition of numeracy and literacy skills. Second, the variance in performance between the eight NUTS-2 regions highlights the need for targeted educational policies and interventions to address these geographical inequalities and ensure more equitable opportunities for skill development across the country. This exploratory finding should be further considered in studies discussing causes of regional disparities in skills acquisition in Romania. Third, our findings indicate a negative trajectory for numeracy and literacy development with performance gradually declining. This trend suggests generational effects on skill levels, potentially reflecting shifts in educational policies, pedagogical methods and cognitive ageing processes. The nuanced understanding of how age affects skill development emphasises the importance of lifelong learning initiatives to support skill maintenance and improvement across all age groups.

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### Ethics Statement

This article does not contain any studies with human participants performed by any of the authors.

### Consent

This article does not contain any studies with human participants performed by any of the authors.

### Conflicts of Interest

The authors declare no conflicts of interest.

### Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request. All relevant data are within the manuscript and its Supporting Information files.

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### Endnotes

<sup>1</sup> The final response rate of the study was 66.8%. To correct for any structural discrepancies caused by non-responses and refusals, the sample was weighted according to socio-demographic variables. This weighting used preliminary data from the 2021 Population and Housing Census (RPL2021), provided by the National Institute of Statistics.

<sup>2</sup> The e-PASS test employs classical test theory (CTT) rather than item response theory (IRT) as applied in PIAAC. CTT focuses on the total test score as a reflection of an individual's ability, with assumptions about the reliability and validity of the test items. This approach allows for a straightforward interpretation of test results.

<sup>3</sup> The utilisation of mixed models is particularly pertinent in this context, as it allows for the consideration of both fixed and random effects, thereby providing a more nuanced understanding of the factors that contribute to educational outcomes.

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### Supporting Information

Additional supporting information can be found online in the Supporting Information section.

## Appendix A

**TABLE A1** | Descriptive statistics.

Variable	N	Mean	Std. Dev.	Min	Max	Range
Numeracy score	4087	247.994	144.394	-155.87	706.26	862.12
Literacy score	4087	228.139	64.105	20.86	354.45	333.59
Non-formal education in the last 12 months	4087	—	—	0	1	1
Age	4087	48.00	18.453	15	100	85
Gender	4087	—	—	0	1	1
Residency	4087	—	—	0	1	1
Years spent in education	4087	14.1	4.67	0	34	34
Regional GDP growth rate	4087	0.096	0.005	0.082	0.102	0.020
Regional unemployment rate	4087	5.793	2.092	2.7	8.8	6.1
Regional employment rate	4087	68.752	8.402	55.4	87.4	32.0
Teachers—students' ratio	4087	0.069	0.004	0.060	0.074	0.014

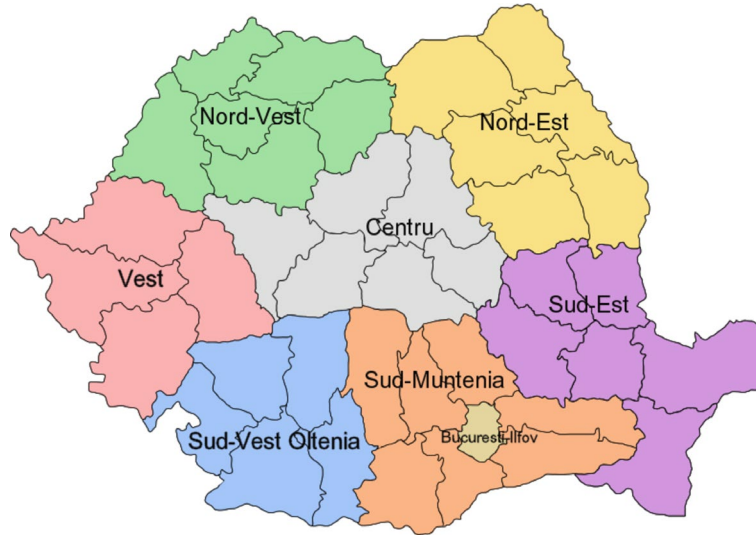
**TABLE A2** | Description of the variables.

Variable name	Measure
Numeracy score	<p>Score computed based on the e-PASS test (UNESCO). The test evaluates the cognitive skills of the Romanian population aged 15 and over. This test is composed of 15 questions, of which 5 measure literacy skills (literacy grade: F00001 F00002 MB2010 MB2011 MB2012) and 10 measure numeracy skills (basic math skills: F00003 F00004 F00012 MB2008 MB2009 MB2001 MB2002 MB2003 F 00005 F00010). The theoretical range of variation of the scores obtained in this test is [0; 800], where 800 represents the maximum score of cognitive skills.</p> <p>The scores obtained in the cognitive test, evaluating the literacy and numeracy competencies of the surveyed population, allow also for the illustration of the population distribution in three distinct competency categories to aid in the interpretation of the raw scores. The competency levels, based on data from PIAAC, are below level 1 (&lt; 176 points), level 1 (176–226 points), and level 2 (&gt; 226)</p>
Literacy score	<p>Score computed based on the e-PASS test (UNESCO). The test evaluates the cognitive skills of the Romanian population aged 15 and over. This test is composed of 15 questions, of which 5 measure literacy skills (literacy grade: F00001 F00002 MB2010 MB2011 MB2012) and 10 measure numeracy skills (basic math skills: F00003 F00004 F00012 MB2008 MB2009 MB2001 MB2002 MB2003 F 00005 F00010). The theoretical range of variation of the scores obtained in this test is [0; 800], where 800 represents the maximum score of cognitive skills.</p> <p>The scores obtained in the cognitive test, evaluating the literacy and numeracy competencies of the surveyed population, allow also for the illustration of the population distribution in three distinct competency categories to aid in the interpretation of the raw scores. The competency levels, based on data from PIAAC, are below level 1 (&lt; 176 points), level 1 (176–226 points), and level 2 (&gt; 226)</p>
Non-formal education in the last 12 months	<p>The respondents were asked if 'In the last 12 months, that is, from... &lt; name of appropriate month &gt; to date, have you participated in any of the following activities with the intention of improving your knowledge or skills in any field (including those related to your passions/hobbies)? It can be activities carried out both during free time and during working hours'. There were 4 possible answers: a course? (1) A workshop or seminar? (2) On-the-job training? (3) Private lessons? (4). The final variable was computed as a dummy variable taking the value of 1 if the respondent declared they participated in at least one type of non-formal education in the last 12 months, and 0 otherwise</p>
Age	The age of the respondent in years
Gender	Dummy variable equal to one if respondent is female, zero otherwise
Residency	Dummy variable equal to one if respondent states having an interest in economics. The variable is based on the following question: 'I am very interested in economic questions'
Years spent in education	The variable was computed based on eight item question asking respondents 'Could you tell me, for each of the following levels (there were eight levels of education), how many years of study you have had? Repeated years are not taken into account, and years mean completed years'. This variable was also recoded as a categorical variable on three levels (1) low education, (2) medium education, (3) higher education

(Continues)

**TABLE A2** | (Continued)

Variable name	Measure
Regional GDP growth rate	The data was collected from Eurostat database
Regional unemployment rate	The data was collected from Eurostat database
Regional employment rate	The data was collected from INS database
Teachers—students' ratio	The data was collected from INS database



**FIGURE A1** | NUTS2 statistical regions of Romania. *Source:* Taken from here: NUTS statistical regions of Romania.



**FIGURE A2** | NUTS3 statistical counties of Romania. *Source:* Taken from here: NUTS statistical regions of Romania.