



THE CHALLENGES OF DIGITIZING THE EDUCATION SYSTEM IN GEOGRAPHIC AREAS WITH DEVELOPMENT DISPARITIES: A CASE STUDY OF OLTENIA COUNTY, ROMANIA

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ABSTRACT

Digitalization is an essential vector of global transformation, which, through the integration of digital platforms and artificial intelligence in education, is bringing about profound changes in teaching, learning, and assessment, as well as structural changes in society. **Objectives:** The objective of the research is to understand how a county with significant development disparities uses the opportunities offered by digitization as a solution for optimizing territorial management policies. The research identifies and describes the uneven distribution of investments and purchases of IT equipment for education, as well as highlighting patterns of spatial distribution of digitization in the education system. **Methods:** The research used data provided by the SICAP, the electronic platform that ensures the transparency of the public procurement process and procedures in Romania, which includes relevant indicators on public procurement in the education system, 2007–2024. Indicators such as the number of public procurement procedures associated with the digitization of education and budget allocations, broken down annually and by place of residence (urban/rural), were analyzed. Data processing was performed in Python/JupyterLab (Pandas, Matplotlib, Seaborn), and territorial distributions were evaluated in QGIS using choropleth maps and bivariate maps. **Results:** Disparities in the digitization of the education system in Olt County have a clear territorial structure, organized into clusters of advantages, concentrated in urban centers and more developed peri-urban areas, where infrastructure, educational resources, human capital, and administrative capacity are concentrated, and clusters of vulnerability, specific to peripheral rural areas. **Conclusions:** Spatial models offer an essential methodological advantage when analyzing regional disparities in the digitization of education, in order to understand "where" the phenomenon occurs and, above all, "how" it spreads and amplifies across the territory.

Keywords: digitization, education system, territorial disparities, territorial system, territorial management, Olt, Romania

JEL classification: I25, I26, I 28, R11

Paper type: Research article.

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INTRODUCTION

Digitalization has become a fundamental driver of economic and social transformation in the twenty-first century, profoundly reshaping the functioning of economies, institutions, and communities. Whereas early



generations of information technology were primarily focused on data storage and processing, contemporary digital systems operate as integrated and interconnected ecosystems that redefine production processes, organizational models, and social interactions. Within this framework, big data analytics, artificial intelligence, and the Internet can no longer be considered independent technological tools, but rather interrelated components of a continuous and systemic process of digital transformation. This process exerts a direct influence on economic competitiveness, institutional efficiency, and social relations (Downes & Nunes; 2013; Alcacer, 2016). The existing body of specialized literature increasingly frames these dynamics within the context of the “fourth industrial revolution,” characterized by a persistent co-evolution between technology and society, in which technological innovation drives social change while societal demands and pressures simultaneously accelerate technological advancement (Andronache et al., 2016; Tekic & Koroteev, 2019).

Within the educational domain, digitization is increasingly regarded as an inevitable and necessary advancement, given its substantial potential to reshape contemporary societies. From this perspective, digital technologies are frequently associated with a range of anticipated positive outcomes, including enhanced student engagement, improved learning experiences, and a reduction in school dropout rates. (Selwyn, 2016).

The role of digitization in education is not limited to infrastructure, equipment, or simple tools introduced in the classroom. The transition from the traditional model to a flexible and adaptive model can contribute to greater educational equity by expanding opportunities for isolated or disadvantaged areas and reducing social inequalities (Viccko, 2016; Wagner, 2018; Kamalov et al., 2023).

Digital transformation involves a shift in the educational, cultural, and pedagogical paradigm, redefining learning processes, capitalizing on the diversity of students' cognitive styles, and strengthening their autonomy. Used ethically and strategically, digitization can become a strategic pedagogical resource capable of amplifying the education system's ability to create personalized learning environments geared toward developing the skills of the future (Dede et al., 2017).

The literature on the subject addresses the digitization of the education system from the perspective of developed areas, leaving peripheral regions, where resources and adaptability are limited, in the background. Furthermore, access to advanced technologies is not universal (Brandsen & Honingh, 2016), and the digital divide is amplified not only by a lack of infrastructure (Osborne et. al, 2016), but also by economic (Wong & Park, 2014), socio-political (Nograšek & Vintar, 2014; Mutsvairo & Ragnedda, 2018), and cultural factors (Warschauer, 2003) that influence people's ability to use technology (Mergel, Edelman & Haug, 2019; Ragnedda & Gladkova, 2020; Jamil; 2021).

The digital transformation of administration is inseparable from the digitization of the education system, as schools function as social infrastructure for skills training, which enables the effective use of digital services and the participation of information in public life (Cooke, 2001; Meijer, 2015). In terms of public value, as defined in Moore's (1995) classic interpretation, digitization produces sustainable results only to the extent that it simultaneously integrates citizen and economic perspectives (Bryson, Crosby & Bloomberg, 2014) into



a collaborative governance framework oriented toward co-design and co-production (Nambisan et al., 2017; Curran, 2020; Lindgren & van Veenstra, 2018; Coenen et al., 2017).

The spatially explicit modeling of education system digitization at the level of territorial administrative units represents a significant analytical advance, as it enables a shift from broadly uniform, highly generalized policy frameworks toward evidence-based and territorially differentiated interventions. By explicitly accounting for local specificities, this approach enhances the relevance and effectiveness of decision-making processes. Moreover, the application of high-resolution spatial autocorrelation techniques allows for a more precise differentiation between localized effects and broader regional patterns, thereby strengthening the analytical robustness of the results. As such, the proposed framework provides a more nuanced and empirically grounded basis for the design and implementation of public policies aimed at reducing digital disparities within the education system.

METHODOLOGY

The starting point for the creation of the spatial model of the digitization of the education system is the database provided by SICAP, the electronic platform that ensures the transparency of the public procurement process and procedures in Romania 2007–2024, with relevant indicators for the characterization of public procurement for the digitization of the education system: the number of procurement procedures and the budgets allocated for the digitization of the education system. For the revelation of the analysis, for certain indicators only the 2016-2024 data were used because only from 2016 all public acquisitions were initiated through SICAP, for 2007-2015 the uploading of data to the platform was optional. In order for the analysis to be carried out in a spatial profile, the tabular data were organized at the level of the territorial units, and the social dimension of the distribution was captured by differentiating the living environments (urban/rural). This stage was important because digitalization and related public activities tend to manifest themselves differently depending on the level of development, and the living environment is one of the most sensitive predictors of access to resources, infrastructure and administrative capacity. For the school population, classrooms and the number of computers and IT equipment, the data provided by the National Institute of Statistics through the Tempo Online platform were used.

The spatial model comprises two variables: "amounts" and "procedures." The "amounts" variable was used to capture the financial dimension of public procurement, i.e., the volume of resources mobilized in a given territory, while the "procedures" variable was used to assess administrative capacity. These two dimensions were considered complementary: a territorial unit may have high investments but a low number of procedures (one-off, large-scale investments), or, conversely, it may have a large number of procedures but relatively small allocations (fragmented activities, small-scale projects). For this reason, a bivariate representation was chosen, capable of simultaneously rendering the two dimensions and avoiding simplified interpretations based on a single variable.



The bivariate map was constructed by designing an appropriate color scheme, as readability and visual comparability are essential conditions for correct interpretation. For each variable, a color palette divided into four classes was selected, designed so that the color intensity increases gradually as the values increase. In the next stage, the two palettes were integrated into a 4×4 bivariate matrix, resulting in 16 distinct color combinations. The matrix was organized and labeled using a mixed system, with A–D on the horizontal axis and 1–4 on the vertical axis, to allow immediate identification of each bivariate class and its relation to the relative intensity of the two variables.

Data processing and effective implementation of cartographic representation were performed in QGIS 3.40.11 "Bratislava," following a phased workflow. In an exploratory phase, univariate representations were generated for "amounts" and "procedures," using classification schemes adapted to the internal distribution of each variable. This stage served to validate the consistency of the data and establish the reclassification thresholds, avoiding the introduction of arbitrary classes that would distort the result.

The first field, associated with the sum variable, is of type integer and groups the values into four intervals (1–4), set based on the upper limit of the variable (500001). The classification was performed using the expression:

```
CASE WHEN "sume" > 500001 THEN 4
WHEN "sume" <= 500001 AND "sume" > 100001 THEN 3
WHEN "sume" <= 100001 AND "sume" > 50001 THEN 2
ELSE 1
END
```

For the procedures variable, a string field was added, in which the values were divided into four symbolic categories (A–D), established by the thresholds 501, 101, and 11, according to the formula:

```
CASE WHEN "proceduri" > 501 THEN 'D'
WHEN "proceduri" <= 501 AND "proceduri" > 101 THEN 'C'
WHEN "proceduri" <= 101 AND "proceduri" > 11 THEN 'B'
ELSE 'A'
END
```

Based on these two reclassified fields, a third attribute, *bivariat_var*, was constructed, combining the values of the two classifications by concatenation:

```
concat("proceduri_var", tostring("sume_var"))
```

The resulting codes (such as A1, B3, D4) indicate the position of each territorial unit in the bivariate matrix and are directly associated with the color scheme. Subsequently, the vector layer was symbolized according to the new bivariate variable, using the previously designed 4×4 palette. The map was exported in .svg format to allow for additional graphical adjustments. Composition elements such as the bivariate legend, map frame, and markers for locating the study area were integrated into Inkscape 1.3.2. The final representation clearly reflects the simultaneous distribution of the two variables and highlights the spatial patterns resulting from their interaction, providing a relevant visual basis for territorial analysis (Figure 1).

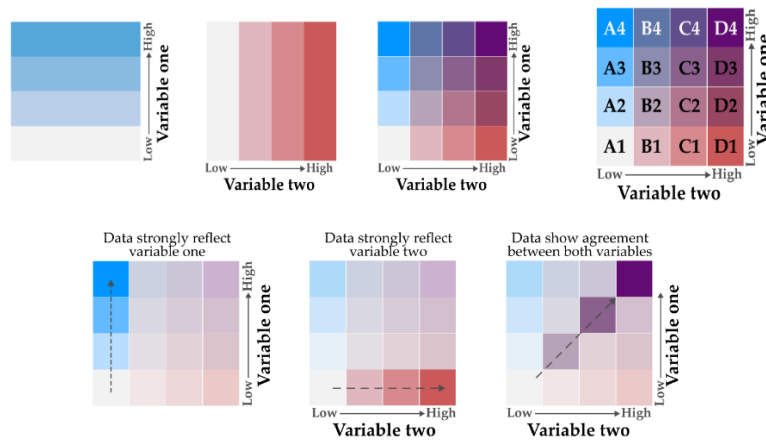


Figure 1. Stages of creating the bivariate matrix

RESULTS

The distribution of budgets allocated in Olt County for the digitization of the educational system in relation to the school population indicates an uneven territorial development, with urban centers and a few localities with high administrative performance that attract substantial amounts, while many municipalities remain in the register of low or non-existent funding (Figure 2). This configuration supports the idea that, beyond needs, local administrative capacities to turn funding opportunities into eligible and implementable projects are decisive, and future policies should aim not only at allocating resources, but also at strengthening administrative capacity.

In terms of the amounts allocated for the digitization of the education system, most local authorities fall into the category of allocations below €50,000, a sign that interventions were, in many cases, sporadic and small in scale (Figure 3). This pattern may reflect either a strategy of dispersing resources across minor projects or recurring difficulties in preparing larger projects (documentation, co-financing, technical capacity), especially in localities with small administrations. In contrast, there are a few centers with very large allocations (over €500,000), which function as true "peaks" of investment. Around urban centers, there is a higher density of funding and a more consistent presence of higher categories, which is consistent with demographic pressure, their economic role, and infrastructure that requires costly interventions.

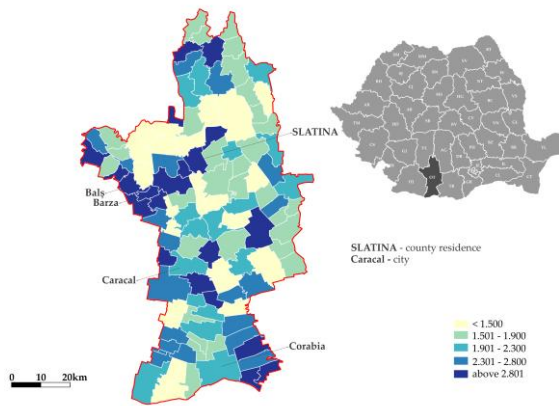


Figure 2. The ratio between the cumulative value of the budget allocated to the digitization of the education system and the average school population (2016-2024), in Olt County. *Source:* INS, SICAP.

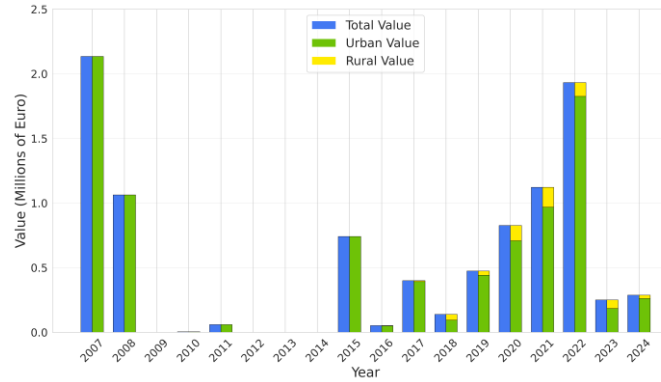


Figure 3. Evolution of budgets allocated to the digitization of the education system by living environment, 2007-2024
Source: SICAP.

The ratio between the cumulative value of the budget allocated to the digitization of the education system and the average number of classes in the period 2016-2014 shows an uneven territorial dispersion, with most municipalities registering low or almost non-existent activity, which suggests limitations of administrative capacity and constraints of human and financial resources (Figure 4). In contrast, high values are concentrated in the main cities and their vicinity, where high values of the indicator are observed, especially in the municipality of Slatina, but also in the cities of Caracal, Balș, and Corabia. This pattern outlines an urban-rural polarization model, with the urban environment appearing to be more active in attracting, planning, and managing digitization projects, while the rural environment lags behind, even though values have increased since 2016 (Figure 5).

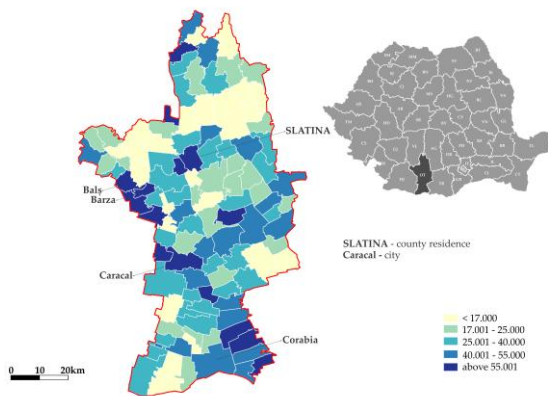


Figure 4. The ratio between the cumulative value of the budget allocated for the digitization of the education system and the average number of classrooms (2016-2024), in Olt County.
Source: INS, SICAP

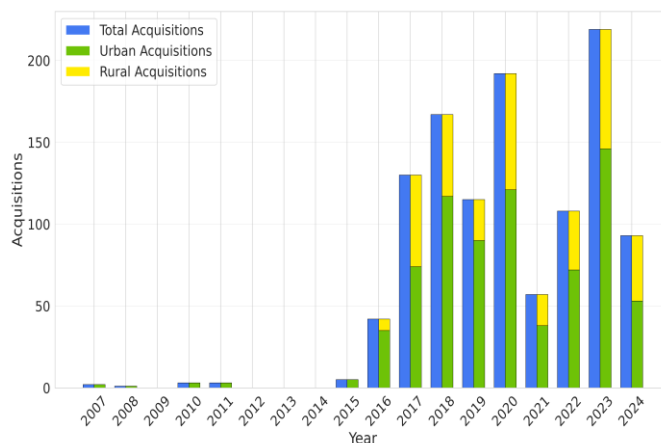


Figure 5. Evolution of the number of public procurement procedures for the digitization of the education system, by living environment, 2007-2024.
Source: SICAP

The spatial distribution describes a spatial pattern, with high-performing urban centers and rural peripheries lagging behind. There is a direct correlation between the size of the locality, the available resources, and the intensity of digitization processes, which reveals a territorial inequality in the implementation of policies for the digital transformation of education. The ratio between the cumulative value of the number of computers and IT equipment and the average school population follows the logic of regional development, concentrated in urban centres and areas with geographical accessibility, diffuse and fragmented in rural areas, indicating the need for territorial balancing policies to reduce digital gaps between schools (Figure 6). Figure 7 illustrates the evolution of the share of financial resources in the digitization of the education system compared to other areas. The dynamics observed highlight significant changes in funding priorities over time, reflecting both the economic context and institutional strategies. At the beginning of the period analyzed, between 2007 and 2010, funds for digitization were concentrated almost exclusively in education, which accounted for over 95% of the total, with the first financial year of the European Union offering numerous opportunities for the education system. Figure 7 highlights a fluctuating trend in investments in the digitization of education, characterized by an initial phase of expansion, followed by diversification and, subsequently, a decline in the relative importance of this area. This trend raises questions about the long-term sustainability of digital and educational development and highlights the need for a coherent investment strategy.

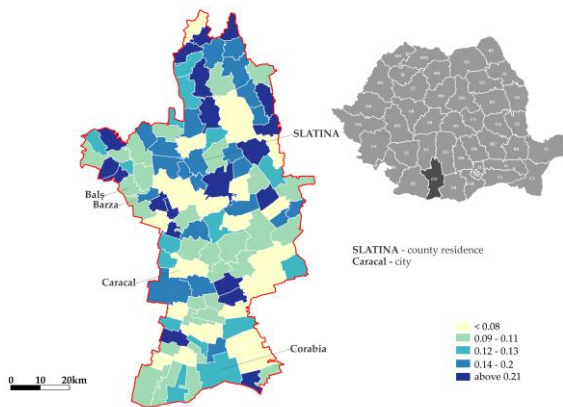


Figure 6. The ratio between the cumulative value of the number of computers and IT equipment and the average value of the school population (2016-2024), in Olt County.

Source: INS, SICAP

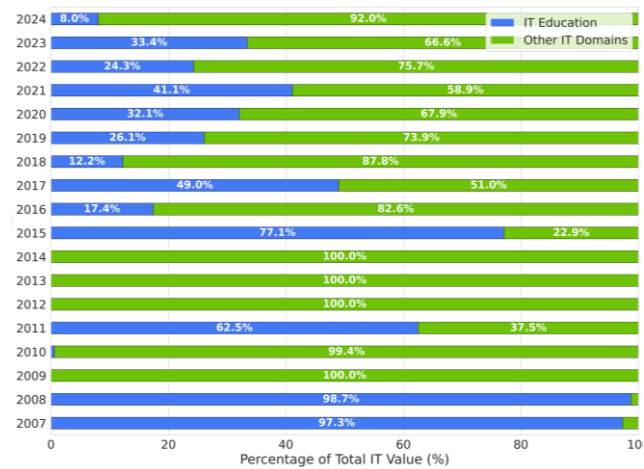


Figure 7. The evolution of the share of public procurement for the digitization of the education system in relation to other expenditures allocated to the digitization of other areas.

Source: SICAP

Figure 8 highlights the evolution of the share of public procurement for the digitization of the education system between 2007 and 2024, broken down by urban and rural areas. From a broad temporal perspective, the data reveal a digitization process characterized by discontinuities, territorial asymmetries, and a marked dependence on exogenous contextual factors. The analysis highlights a model of education digitization characterized by ad hoc responses to external shocks rather than a coherent and continuous strategy. The



persistence of differences between residential environments underscores the need for integrated public policies aimed at reducing territorial disparities and strengthening institutional capacities.

Figure 9 captures the evolution of the ratio between direct and competitive procedures in the digitization of the education system, providing a relevant perspective on public activity practices and institutional capacities between 2007 and 2024. From a longitudinal perspective, a pattern emerges that is characterized by alternating between formalizing procedures and resorting to simplified mechanisms, closely linked to the economic, regulatory, and social context.

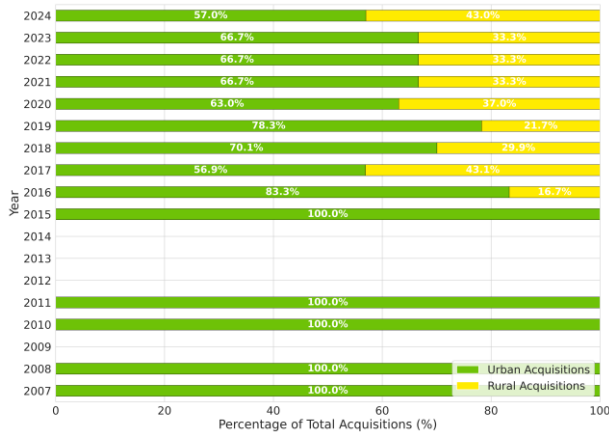


Figure 8. Evolution of the share of public procurement for the digitization of the education system, by living environment, 2007-2024.
 Source: SICAP.

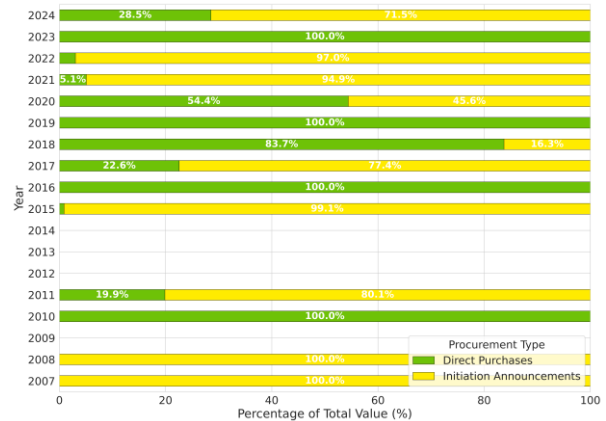


Figure 9. Evolution of the ratio between direct purchases and initiation of procurement procedures for the digitization of the education system, 2007-2024.
 Source: SICAP.

Figure 10 highlights a budget allocation pattern strongly influenced by cyclical factors, in which systemic crises generate sudden increases in investment, followed by periods of adjustment. The distribution of budgets across types of public goods reflects the structural tension between the need for rapid intervention and the imperatives of efficiency, transparency, and sustainability. These findings underscore the need for a coherent, long-term budgetary strategy. A significant jump in budgets is evident in the period 2020–2022, when there is an increase in financial allocations for digitization, particularly through their direct use. This reconfiguration is closely linked to the context of the COVID-19 pandemic, which required urgent interventions to ensure the continuity of the educational process. In this exceptional context, direct activities absorbed a substantial part of the resources, becoming the main instrument for implementing digitization policies, to the detriment of competitive procedures. Figure 11 shows the evolution of the number of public procurement procedures for the digitization of education (2007–2024), by type of procurement, providing indications of the intensity of interventions and the instruments used in the implementation of public policies. In 2007–2012, the number of procedures was low, suggesting that digitization was not a priority and that institutional capacity to initiate and manage formal procedures was limited. Between 2013 and 2019, there was a gradual increase, especially in competitive procedures, against the backdrop of the consolidation of the regulatory framework and the use of European funds, but the trend was uneven, indicating inconsistent planning and implementation. In 2020–2021, there is a sharp jump, especially in direct improvements, which can be explained by the pressure of the

pandemic and the need for rapid provision of equipment to ensure the continuity of education. Figure 12 reveals a pattern of evolution characterized by significant fluctuations, determined both by structural constraints and circumstantial factors.

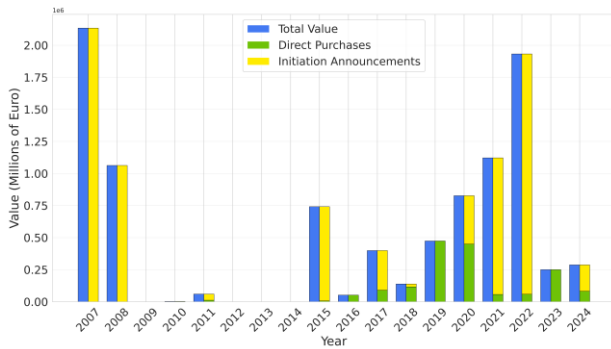


Figure 10. Evolution of budgets allocated for procurement for the digitization of the education system, by type of public procurement, 2007-2024
 Source: SICAP.

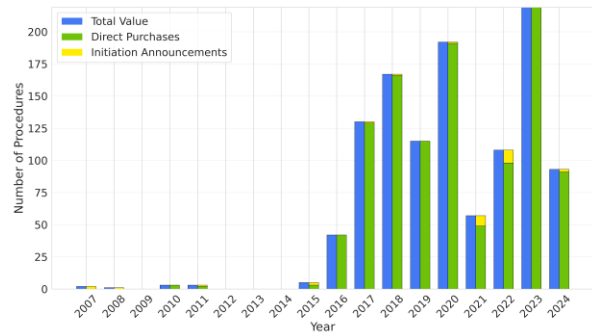


Figure 11. Evolution of the number of public procurement procedures for the digitization of the education system, by type of public procurement, 2007-2024
 Source: SICAP.

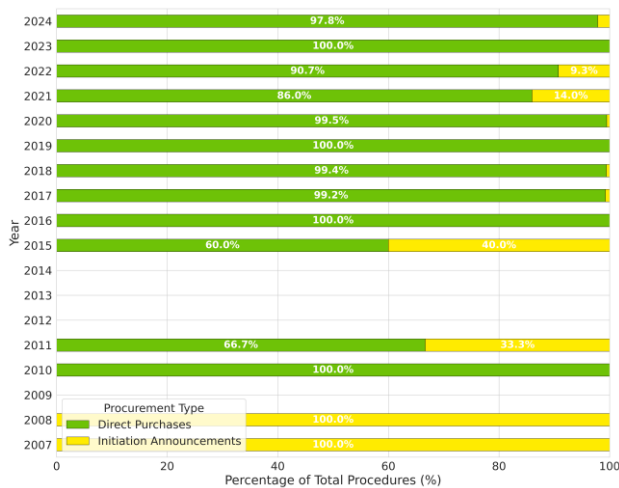


Figure 12. Evolution of the ratio between types of public procurement, 2007-2024
 Source: SICAP.

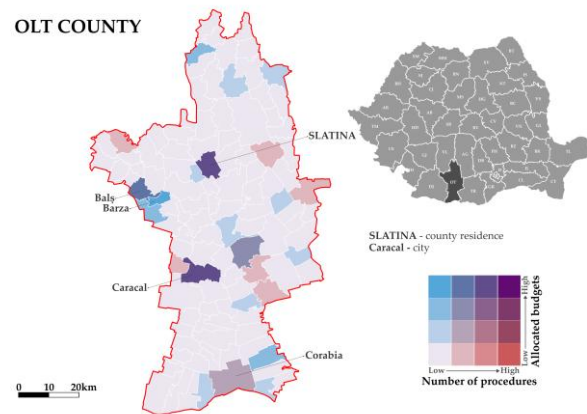


Figure 13. The ratio between the number of procedures initiated and the budgets allocated for the digitization of the education system.
 Source: SICAP.

The ratio between the number of procedures initiated and the budgets allocated for the digitization of the education system reflects the conflict between the need for rapid intervention and the requirements of public governance, highlighting the importance of strengthening strategic planning and institutional capacities to ensure the sustainable and transparent digitization of the education system (Figure 13).

DISCUSSION

Taken together, these results support the idea that the digitization of education is not just a technological process, but a deeply territorialized one, in which space structures the opportunities and conditions for



transformation. Spatial patterns indicate the formation of clusters of advantage, usually around urban centers and well-connected localities, and clusters of vulnerability in the peripheries and dispersed rural areas. Consequently, the research question is clarified: digitization is not distributed evenly, but follows territorial patterns of resource accumulation and reproduction of inequalities, which explains the persistence of gaps even in the context of increased funding.

Initiatives to increase technological resources in the education system should be understood as structural policies, not as one-off interventions. Digitization produces long-term social benefits when it is geared towards functionality (real use), equity (prioritizing vulnerable areas), and sustainability (maintenance, training, evaluation). Under these conditions, the effectiveness of the educational technology value chain increases and digitization becomes not just technical modernization, but an investment in social cohesion and development (Pierce & Cleary et al., 2024; Wang et al., 2024).

The results suggest that digital progress spreads through neighborhoods and institutional networks (spillover effects), which can strengthen already high-performing hubs and create pockets of delay where connectivity, skills, and operational support are weak. In this sense, the same intervention can produce different results in the functioning of the local system: functional infrastructure, digital skills, maintenance, and pedagogical support (Godin & Terekhova, 2021).

Digital technologies can significantly improve educational equity in rural areas only if they are combined with connectivity, equipment, solid professional development for teachers, and inclusive learning models. Without these, they tend to reproduce or even amplify existing inequalities between rural and urban areas (Sindakis & Showkat, 2024; Okoye et al., 2025).

The literature consistently emphasizes that omitting the spatial dimension from such analyses can distort statistical inference, territorial dependencies introduce systemic correlations between analyzed units, and treating them as independent observations can lead to inefficient or biased estimators and, implicitly, to erroneous interpretations of the relationships between variables (Herman et al., 2020; Akbari et al., 2021; Peptenatu et al., 2024). In this sense, integrating the spatial dimension into modeling is not just a technical refinement, but a prerequisite for robust diagnosis of disparities and for informing public policy decisions (Worrall & Bond, 1997; Greenberg et al., 2025).

A key advantage of the spatial approach is its ability to rigorously explain spillover effects and separate direct effects from indirect ones. Unlike classical models, where impact is interpreted predominantly locally, spatial models allow quantification of how a change in one territory is transmitted to other territories through the connectivity structure (Pintilii et al., 2015; Diaconu et al., 2019; Zhang et al., 2022; Fantechi & Fratesi, 2023). Consequently, the proposed methodology contributes to the development of established approaches to the analysis of territorial processes and can contribute to understanding the mechanisms of spatial accumulation of advantages and disadvantages for development (Băloi et al., 2024; Burton et al., 2024; Peptenatu et al., 2025).



The importance of these methodologies becomes even more pronounced when the digitization of education is interpreted as a process with systemic effects on socio-economic development. Digitized education functions as a mechanism for producing and distributing human capital, with direct implications for productivity and economic performance (Pintilii et al., 2017; Băloi et al., 2023).

CONCLUSION

The digitization of the education system can become a strategic tool for reducing development disparities in poor regions, insofar as it functions as a mechanism for compensating for territorial and socioeconomic disadvantages. In such regions, the main barriers – limited access to infrastructure, a shortage of educational resources, a lack of specialized staff, and distance from centers of opportunity – tend to accumulate and reproduce vicious circles of underdevelopment. By expanding connectivity and access to digital resources, digitization can reduce these structural constraints, giving students and teachers the opportunity to use up-to-date educational content, participate in assisted learning activities, and benefit from pedagogical support that would otherwise be unavailable.

In the area studied, which is representative of development disparities in Romania, there are pockets of high investment intensity in the digitization of the education system, with the municipality of Slatina playing the main role as a hub, through the association of a large number of procedures with substantial budget allocations. A similar profile is observed in Caracal, Balș, and Corabia, suggesting a higher institutional capacity to attract and manage budgets for digitization, as well as the existence of an educational and administrative infrastructure that facilitates project implementation.

Intermediate values are usually recorded in peri-urban areas, with localities in the vicinity of urban centers tending to have moderate procedure density, but accompanied by a comparatively low budget. This pattern indicates either smaller-scale projects or an early stage of digitization, in which interventions are still limited in scale. At the same time, proximity to the city acts as an indirect advantage, through access to better-developed administrative and educational networks that can support the initiation and implementation of procedures. In contrast, rural areas are characterised, in most cases, by low activity and minimal budget allocations, reflected in a low number of procedures. This distribution can be interpreted as the result of reduced administrative capacity, a shortage of specialized project management personnel, and structural difficulties in accessing national and European funding. The concentration of large-scale projects in a few centers and the dispersion of small amounts throughout the rest of the territory can produce asynchronous development trajectories in terms of access to public services, infrastructure quality, and economic attractiveness.

In particular, access to personal digital technology and the internet has an equalizing effect in poor communities, as it reduces the costs of accessing information and learning. Mobile devices and educational platforms can at least partially compensate for the lack of libraries, modern teaching materials, or remedial



programs. In these circumstances, digitization is not just a matter of equipment, but takes on a social function that increases the chances of academic success for disadvantaged students.

Integrating ICT into schools in disadvantaged regions also has the potential to reduce educational inequalities that subsequently translate into economic inequalities. A digitized school can offer higher quality teaching by diversifying teaching methods and enabling personalized learning, which is essential in classes with diverse students and insufficient human resources. In addition, developing digital skills in school increases the chances of entering the labor market and accessing better-paid jobs, which contributes to strengthening local human capital. In poor regions, this dimension is critical: increasing digital skills can reduce the vulnerability of precarious jobs and facilitate the transition to more productive economic activities. Open and distance learning programs can amplify this effect by enabling mass access to education and training, particularly for groups facing constraints of mobility, time, or cost. In poor regions, where educational provision is often limited, such programs can expand access to quality courses, certifications, and resources, reducing dependence on local infrastructure.

The implications for public policy are clear: digitization can function as a genuine driver of development only if it is conceived as an equitable, context-sensitive process adapted to regional specificities. A uniform, one-size-fits-all approach risks reinforcing pre-existing spatial and social disparities by consolidating digital development within already advantaged clusters. In contrast, targeted interventions that integrate investments in digital infrastructure with teacher training, pedagogical support, system maintenance, and active community involvement demonstrate a greater capacity to mitigate territorial inequalities and enhance educational outcomes.

Beyond their policy relevance, these findings also highlight several pathways for future research. First, there is a need for longitudinal studies capable of capturing the dynamic effects of digitization policies over time, particularly in disadvantaged and peripheral regions. Second, researchers should further refine spatially explicit analytical frameworks by incorporating qualitative dimensions, such as institutional capacity, local governance arrangements, and socio-cultural attitudes toward digital technologies. Third, greater attention should be paid to multilevel interactions between national strategies, regional development trajectories, and local educational practices, in order to better understand how digital inequalities are produced and reproduced across scales.

Ultimately, advancing research in this field requires an integrated methodological approach that combines spatial analysis, policy evaluation, and educational research. Such an agenda would not only strengthen the empirical foundations of digital education studies but also support the design of more effective, evidence-based policy interventions aimed at fostering inclusive and territorially balanced digital transformation in education.

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All authors have read and agreed to the published version of the manuscript.

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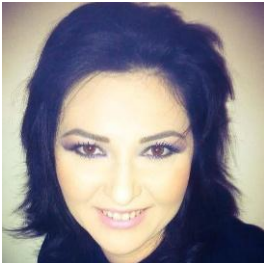


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