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Spatially uneven service pressure under population decline: evidence from Hungarian primary education

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Abstract This study examines how population decline reshapes the spatial distribution of teaching intensity in Hungary's primary-education system. Combining site-level administrative data with census-based demographic indicators, it analyses whether higher teaching hours per student in shrinking municipalities reflect compensatory provision or the structural consequences of low enrolment and small class size. The findings suggest a spatially uneven "double pressure": municipalities facing demographic shrinkage often also display higher concentrations of social disadvantage, while school sites in these areas show elevated per-student teaching intensity. Decomposition of the teaching-hours-per-student indicator shows that this pattern is driven primarily by structural constraints, especially smaller class size, rather than by a systematic expansion of teaching hours per class. Spatial analysis further reveals a territorial overlap between high teaching intensity and disadvantaged student composition, while the share of students with integration, learning, and behavioural difficulties follows a distinct U-shaped relationship with local population change. The article argues that in shrinking regions, high per-student teaching intensity should not be interpreted automatically as inefficiency; it may also reflect the organisational cost of maintaining local access within a centralised public system. More broadly, the Hungarian case shows how demographic shrinkage can generate uneven local service pressures within centralised public systems.

Keywords Population decline · Spatial inequality · Shrinking regions · Service provision · Spatial demography · Hungary

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Introduction

Over the past decade, the spatial organisation of public education has increasingly been shaped by demographic change, as population decline and aging have altered the local conditions of service provision unevenly across the settlement system. On the one hand, the concentration of disadvantages and social exposure in numerous regions intensifies the need for compensation. However, demographic decline—particularly in peripheral, low-density municipal environments—directly reshapes institutional scale and class structures (Christiaanse, 2020; Kulcsár & Obádovics, 2016; Máté et al., 2024; Pressman, 2007; Szőke et al., 2025). While population decline and aging are European-wide trends, they are highly differentiated regionally, outlining divergent local trajectories (Haase et al., 2016; Majdzińska, 2024; Rees

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et al., 2012; Zienkiewicz & Zienkiewicz, 2024). Consequently, educational provision in shrinking spaces does not emerge as a uniform challenge but rather as territorially distinct adaptation constraints that simultaneously impact access, capacity, and quality inequalities (Béres, 2025; Kučerová et al., 2020; Pirisi et al., 2025; Wojewódzka-Wiewiórska & Stawicki, 2020). In such contexts, demographic shrinkage may also involve selective migration processes, as more mobile and better-resourced households are often better positioned to leave peripheral or economically weakening areas, thereby altering the social composition of the remaining population (Tagai et al., 2018; Ubarevičienė & van Ham, 2017).

The relevance of age-structural change and declining cohort sizes for public services extends beyond mere population decrease: the shrinking number of school-age children, together with changing dependency ratios, places sustainability pressure on public systems and indirectly manifests in dilemmas of organisation and resource allocation (Nicolae & Amalia, 2020; Rees et al., 2012). In the post-socialist region, this is compounded by uneven transformation, institutional path dependence and the differentiated restructuring of public systems, which have resulted in varying national trajectories, offering a broader comparative framework for interpreting territorial outcomes and inequality patterns (Herbst & Wojciuk, 2017; Smith & Timár, 2010).

In public education provision, demographic shrinkage becomes a critical operational issue, particularly in small settlements, where expectations of local access and organizational minimums (grade levels, groups, subject frameworks) limit purely scale-proportionate adaptation (Andl, 2021; Di Cataldo & Romani, 2024; Kłoczko-Gajewska, 2020; Kroismayr, 2019; Muñozo et al., 2020). In rural Hungary, within the context of rural restructuring and social polarisation, the operation and survival of small village schools are shaped by the tension between local institutional capacities and network constraints (Kovács, 2012; Nagy et al., 2015; Yarwood, 2023). Local capacities refer here to student numbers, staffing possibilities, available buildings, and the ability to organise grades and groups locally, while network constraints include catchment boundaries, distance to alternative schools, transport conditions, and the expectation that primary education remains accessible. Therefore, school closures and mergers are not only administrative reorganisations. In particular, when the last school in a settlement is affected, it may become a politically contested question of local access, everyday community functions, and the capacity of settlements to retain child-related public services (Kassai & Farkas, 2016; Pusztai, 2009; Sőrés, 2009). This does not imply that school closures automatically cause further depopulation. Rather, the relationship between school closure and local decline is context-dependent, although the loss of the last local school may become politically and socially contested because it affects everyday access to basic public services (Barakat, 2015; Uba, 2016).

Empirical studies of resource allocation typically capture institutional differences through financial expenditures, teacher headcounts, or per-capita costs. However, these do not always provide a direct picture of operational burden at the site level. Therefore, the analysis centres on a simple indicator of local service intensity: institutional teaching hours per student (THPS). Its interpretation is intuitive: it expresses the volume of service provision allocated to each student. However, a high THPS value can reflect two distinct logics: it may be interpreted as a surplus related to compensation (e.g. split groups, developmental sessions, targeted interventions) or as a structural consequence of small-scale, fragmented provision, where service obligations are relatively fixed, but student numbers are low, distributing the teaching load across fewer students.

To empirically investigate this distinction, this study decomposes the THPS indicator into its structural components: teaching hours per class and class size (students per class), which together determine the specific teaching load. Analysing these components separately allows us to answer whether the increase in specific teaching load observed alongside demographic decline is driven primarily by decreasing class sizes (a structural constraint) or by changes in teaching volume per class (service adaptation).

Access and the thinning of service points have become key elements of spatial justice in the literature. In this study, spatial justice is understood not as the equal distribution of identical institutional forms but as the territorial capacity of the education system to maintain reasonable access while responding to unequal local needs. The “education deserts” framework, for example, operationalises gaps in educational access through the tension between availability thresholds and local demand–capacity dynamics (Dövényi & Németh, 2018; Petre et al., 2025). This perspective is relevant because the coincidence of high teaching intensity, demographic shrinkage, and social disadvantage may indicate places where maintaining access becomes structurally more demanding and where inequality reproduction is more likely (Hermann & Kisfalusi, 2023).

Given the territorial embeddedness of demographic processes, this investigation interprets settlement network differences through categories of administrative legal status (village, town, large village, city with county rights, county seat, capital district). The breakdown by legal status approximates the varying institutional scale and service conditions of the municipal environment, making it suitable for demonstrating the extent to which the relationship between demographic trajectory and teaching load is a general phenomenon versus where it is particularly intensified.

Finally, based on indicators aggregated to the settlement level, the study uses spatial comparison to examine how administrative categories indicating student composition (disadvantaged, multiply disadvantaged, receiving regular child protection benefits)[1] and the proportion of students with integration, learning, and behavioural difficulties (ILBD) align with specific teaching loads. This step connects to the broader observation that territorial and social inequalities in public education are replicated through multiple mechanisms and that institutional access, segregation, and differing local capacities can collectively form persistent spatial patterns (Hegedűs, 2016a, 2016b, 2023; Rafaj & Némethová, 2024; Velkey, 2022; Zamfir, 2017). From a long-term perspective, specific persistent gradients can be detected in the educational outcomes of border regions and peripheries, providing further context for interpreting the lagging observed in municipal areas (Pénzes et al., 2023). The spatial polarisation of human capital is also supported by patterns of the highest educational attainment (Béres et al., 2025; Béres & Máté 2026), while analyses linking youth employment emphasise the labour market relevance of the educational structure in Central and Eastern European regions (Stefanova, 2024).

Accordingly, the aim of this study is threefold: (1) to present the structural components of THPS and their demographic correlations; (2) to explore how demographic trajectories relate to expected school-site scale and specific teaching intensity by administrative legal status; and (3) to examine the spatial covariance of disadvantage indicators and ILBD with teaching intensity at the settlement level using bivariate maps.

These hypotheses are based on a three-part explanatory model. First, demographic decline may generate structural inertia because nationally regulated grade-level, subject-level, class-size and catchment-related obligations cannot be reduced proportionally with student numbers. Second, the operational adaptation of these obligations is mediated at the maintainer, school-district and school-site levels, where decisions about class organisation, staffing possibilities and network rationalisation are constrained by the existing settlement structure and institutional scale. Third, beyond these legally binding requirements, the professional and spatial-justice expectation that primary education should remain reasonably accessible further limits purely scale-based consolidation. School closures and network rationalisation may therefore become politically contested, especially when the last local school or everyday access to basic education is affected (Uba, 2016). Therefore, the study expects higher THPS in shrinking areas not because decline necessarily produces more generous provision, but because relatively fixed organisational obligations may be distributed across fewer pupils. In line with this explanatory model, our three hypotheses are:

H1 We hypothesise that demographic decline, measured as the decrease in the population aged under fifteen between 2001 and 2022, is associated with higher site-level teaching hours per student (THPS).

H2 We hypothesise that this association is driven primarily by a structural channel: under demographic decline, smaller class size contributes more strongly to higher THPS than changes in teaching hours per class.

H3 We hypothesise that at the settlement level, a high THPS is more likely to coincide with higher ratios of disadvantaged students, multiply

[1] See Béres, 2025; Varga, 2013.

disadvantaged students, and students receiving regular child protection benefits. In other words, social disadvantages and structurally elevated teaching intensity are expected to partially overlap in space.

Literature review

Service organization in shrinking spaces: the dilemma of efficiency and equity

The territorial organisation of public education provision is characterised by persistent tension between two partially conflicting imperatives: rational allocation of resources (cost efficiency, economies of scale, organizational optimisation) and assurance of equitable access (spatial proximity, compensatory mechanisms, provision for special educational needs). Studies focusing on educational equity emphasise that in resource-constrained environments, inequalities in access and quality tend to intensify; therefore, policy decisions must simultaneously address network sustainability and social justice.

Some research also shows that demographic decline does not lead to a single uniform policy response. In some systems, declining cohort sizes may be followed by relatively elastic adjustments in education spending, school size policy, or network rationalisation, especially where cost efficiency and consolidation logics are strongly institutionalised (Ares Abalde, 2014; Kempkes, 2009). However, such adjustments are mediated by national governance structures, school size regulations, access norms, and the political sensitivity of school closures. Therefore, the present study does not assume a simple linear relationship between demographic decline and institutional contraction (Dézsi et al., 2014). Instead, it examines whether the Hungarian case shows signs of structural inertia, where teaching obligations and access expectations remain partly fixed, while student numbers decline.

According to the international literature on cost efficiency and economies of scale, public education services operate with high fixed costs; consequently, small-scale institutions and maintenance units typically exhibit less favourable per-unit indicators (average unit costs) (Agasisti et al., 2022; Blank & Niaounakis, 2019; Mizunoya & Zaw, 2017; Taylor et al., 2025; Titus et al., 2017). Research has pointed out that the correlation between expenditures and service quality (or its proxy variables) cannot be independent of the service environment and organizational scale (Stinson & Krahmer, 1969), while economic models of economies of scale have identified a characteristic "U-shaped" pattern in cost functions, specifically in secondary education (Riew, 1966). However, more recent empirical estimates nuance this picture: methodological assumptions regarding the shape of the cost function (e.g. the application of quadratic forms) can bias the estimated savings potential attributed to institutional consolidation. Flexible models examining the relationship between district size and unit costs have identified multiple optima and transitional plateaus, suggesting that network reorganization cannot be described by a linear gain–loss logic (Schiltz & De Witte, 2017). Similarly, multilevel approaches (maintenance and institutional) highlight that cost advantages stemming from size only partially filter down to the school level: economies of scale are more pronounced in the case of small school sizes, while marginal utility may flatten at larger sizes (Blank & Niaounakis, 2019).

Furthermore, the additional costs associated with rural provision cannot be reduced to a question of size alone. Numerous cost models have confirmed that for schools operating in sparsely populated areas with low student numbers, physical accessibility, maintenance of service portfolios, and human resource structures generate structural surplus burdens that must be distinguished from the simple-size effect (Kolbe et al., 2021). Moreover, the cost implication of small-scale reforms depends on institutional profiles, outputs, and student composition (compositional effect): different cost minimums and specific cost levels can materialise under the same "small school" label (Stiefel et al., 2009). This implies that shaping the institutional network of shrinking regions cannot be narrowed down to the search for a single optimal size, as the organizational and social contexts are inseparable parts of the cost structure.

Spatial inequalities, school composition, and performance: the structuring power of local context

The literature on spatial educational inequalities points out that student composition (compositional effect) and environmental resources (e.g. residential status) are not merely static background variables but rather structuring factors of school success. In urban environments, the profile, resource endowment, and opportunity structure of schools serving residential areas of different statuses differ markedly, which can be interpreted as a central mechanism of territorial and social selection (Bagley et al., 2024; Owens & Candipan, 2019). Population geography approaches examining the intertwining of special educational needs (SEN) and social stratification also highlight that disability and SEN status are deeply embedded in processes of spatial segregation and the unequal distribution of various forms of capital (economic, cultural, and institutional) (Holt et al., 2019).

In declining rural and peripheral areas, these compositional effects may be reinforced by selective out-migration. Research on post-socialist shrinking regions shows that younger, better-educated and more mobile groups are more likely to leave, while older, less educated and less mobile residents are more likely to remain, producing residualisation and socio-spatial polarisation (Tagai et al., 2018; Ubarevičienė & van Ham, 2017; Wiest, 2016; Wiest & Leibert, 2013). In this sense, disadvantage concentration is not only a school-compositional pattern but also a demographic and spatial sorting process connected to long-term local decline.

An important methodological lesson is that student performance and its school-level determinants exhibit a spatially heterogeneous relationship (i.e. spatial non-stationarity). Geographically Weighted Regression and clustering studies on Italian data have confirmed that the same contextual factors (school size, student composition, and baseline competence level) can influence effectiveness with varying strengths and even in different directions across different regions (Sacco & Falzetti, 2021). This recognition has direct relevance for territorial service organisations: instead of standardised policy interventions and normative financing logics, the role of place-specific capacity and needs assessment is becoming increasingly important.

Concentration of disadvantage and special needs: access inequalities and spatial patterns

The territorial concentration of disadvantage not only increases the demand for compensation in a general sense but also differentiates access to special services. For example, the timing of SEN identification has a significant impact on later outcomes, indicating that the "entry points" of the care system (gatekeeping)—diagnosis, identification, and determination of eligibility—are not neutral with respect to future life trajectories (Keating et al., 2025). Simultaneously, social inequalities in access to services are well documented. Based on European examples, a higher socioeconomic status is positively correlated with access to special provisions, suggesting a complex interplay of diagnostic and institutional capacity mechanisms (Halvorsen et al., 2025). Among autistic students, the volume and type of services utilised also follow a characteristic sociodemographic pattern, confirming that the allocation of support services is not purely needs-based but is distorted by social and territorial factors (Hegedűs, 2023; Sturm et al., 2021).

The examination of geographical distribution also reveals that the spatial structure of special pedagogical programs and services is often concentrated in certain areas. A Florida case study indicates that schools offering special programs are typically tied to more densely populated areas, imposing serious transportation and access burdens on families living on the periphery (Rohrer et al., 2019). Policy reviews of rural special education specifically highlight governance and organizational challenges stemming from professional shortages, small school sizes, and large service distances, while emphasising the adaptation potential inherent in local innovations and partnerships (Rude & Miller, 2018). Based on this research, the concentration of disadvantage and special needs is not merely a question of school composition but a factor that fundamentally restructures the territorial capacities of service organisations.

Resource allocation and organizational responses: integration, recombination, and targeted intervention

In rural and peripheral regions, the imperative of resource allocation often calls for integrated service organisation models: these build on inter-institutional cooperation, capacity sharing, and the flexible recombination of professional and material resources. Studies examining resource integration in rural primary education in the Chinese context point out that the expansion of service portfolios and quality improvement can become sustainable through networking, clustering, and resource sharing (Han & Xie, 2025; Wang et al., 2019). A similar equity-based approach prevails in studies discussing the optimisation of rural preschool provision systems, which see the mitigation of territorial inequalities in the coordinated and targeted development of financing, human resource management, and institutional access (Lan, 2025). In a broader interpretation, within the framework of educational equity, the targeted fine-tuning of resource allocation (especially in disadvantaged regions) aims to simultaneously address the sustainability and social-justice dimensions of the system (Zhu & Li, 2025).

The operating environment is thus strained by two processes moving in opposite directions: while demographic erosion generates pressure on the supply side of provision (organizational scale, network density, cost structure), the concentration of disadvantage generates pressure on the demand side (need for compensation, special services). This dual effect directly impacts operational capacities: the provision of basic tasks and the management of differentiated needs collectively increase the capacity stress weighing on local institutions (Kolbe et al., 2021; Rude & Miller, 2018). Fitting into this international discourse, the present study examines the co-movement of demographic scale shifts, the concentration of social disadvantage, and local operational burden (teacher's teaching load). This demand-side pressure may be further intensified where selective out-migration reduces local human capital and weakens the social and institutional resources available to schools and communities (Ouředníček et al., 2011; Tagai et al., 2018).

Hungarian primary education governance and institutional context

Hungarian primary education is generally organised as an eight-grade structure, covering grades 1–8 and corresponding to ISCED 1 and lower secondary ISCED 2 within the same institutional stage. This structure is important for the present analysis because even small school sites must organise provisions across several grades, subjects, and class groups. Since the post-2013 centralisation of school governance, most state-maintained schools have operated under school district centres rather than under direct municipal maintenance. Consequently, local demographic decline does not automatically translate into locally controlled resource decisions; instead, school sites operate within a centralised maintenance and regulatory framework.

In mainstream primary education, class size parameters are regulated nationally (Act CXC of 2011 on National Public Education, Appendix 4). For grades 1–4 and grades 5–8, the statutory minimum is 14 pupils per class, and the maximum is 27. The maintainer may only permit a maximum 20% upward deviation from this limit under specifically defined legal circumstances. The maintainer determines the number of classes to be organised per grade, while the school head decides on the allocation of admitted pupils into classes and groups after consultation with the relevant teaching staff. Catchment areas for mandatory-admission primary schools are defined administratively, and schools providing mandatory admission must take pupils residing in their admission areas.[2]

Therefore, the distinction between legal institutions and school sites is important. While the majority of public education institutions operate at a single site, some consist of a central seat and one or more additional locations. Within these multi-site configurations, certain locations operate as "member institutions", which possess a greater degree of autonomy and maintain their own local management. In this study, the relevant operational unit is the school site, because teaching hours, student headcount, and class structure are jointly interpretable at this level. The term "institution" is used only when referring to the legal organisation; otherwise, the manuscript uses "school site" or "site-level provision unit."

Finally, "resource problems" in small schools with fewer than approximately 150 pupils do not necessarily mean that these schools fall below a formal legal viability threshold. Rather, they refer to organisational fragility. For instance, while the National Public Education Act (Section 4(24)) permits the merging of classes in the lower grades (grades 1–4), it strictly prohibits this practice in the upper grades (grades 5–8). Consequently, a full eight-grade school with low enrolment is legally required to maintain separate grade-level provision for the upper grades,

[2] According to Sect. 50(6) of Act CXC of 2011, schools providing mandatory admission are legally obligated to enrol pupils residing within their designated admission areas, limiting their ability to turn away local students to optimise class sizes.

alongside specialist teaching and support functions with limited student numbers. Under such conditions, these fixed or weakly adjustable teaching obligations are distributed across fewer pupils, which mechanically increases teaching hours per student, even without deliberate over-provision.

In Hungary, the allocation of teaching hours is strictly governed by the National Core Curriculum (NAT) and the associated Framework Curricula. These national standards define the exact minimum number of weekly teaching hours required for each subject per grade across the country. Consequently, baseline teaching hours are allocated on a per-class and per-subject basis. While schools possess a very limited "free timeframe" for local pedagogical profiling, the core instructional volume is completely standardised. This mechanism implies that a small class of 14 students and a large class of 27 students require nearly identical basic teaching hours to fulfill the mandatory curriculum. Importantly, fulfilling this legal minimum does not necessitate optional elements such as group divisions; a school operates entirely lawfully without them. However, since these small schools are typically located in rural settlements, their fragmented network collectively imposes a significant administrative burden on the educational system. Furthermore, ensuring adequate professional teaching staff—particularly subject specialists in STEM—emerges as a widespread structural challenge, often serving as a rule of thumb for the operational difficulties of such institutions.

Methodology

Data sources, linkage, and unit of analysis

Our analysis focuses on the spatial patterns of the trade-off between structural sustainability and structural equity. This study uses aggregated institutional-level administrative data to examine teaching loads as a key dimension of daily resource allocation. The analysis focuses on mainstream primary education in Hungary and captures the operational burden of school provisions, rather than broader institutional performance.

Site-level operational indicators were derived from the KRÉTA[3] administrative system after restricting the dataset to mainstream primary-school provision: total recorded teaching volume, number of students and number of classes.[4] This task-specific filtering was necessary because the same school-site identifier may contain records belonging to other educational tasks or levels, such as upper-secondary grammar school provision, which would distort both student headcounts and teaching volume indicators if included in the primary school sample. In this study, teaching volume refers to the aggregate number of organised weekly teaching hours recorded for the school site, including the additional teaching-hour component recorded in the administrative system, where applicable. Crucially, the data extracted from the KRÉTA system represents the actual, realised volume of teaching hours delivered, rather than merely theoretical allocations or initial subject distribution plans. This means it inherently accounts for the real operational reality, including factual lesson substitutions and completed hours, offering a highly accurate measure of the institutional provision actively sustained by the school site. It is not an individual student timetable and should not be interpreted as the number of lessons received by each student. Rather, it captures the teaching capacity that must be organised at the site level under the national curriculum, class structure, and local pedagogical program. The raw administrative export contains a generic field label referring to "practical training hours," which is used across education types in KRÉTA; in the mainstream primary school subsample analysed here, this should not be interpreted as vocational practical training. Categories indicating student composition were obtained from the Public Education Information System (KIR) database (student headcount, disadvantaged [DS], multiply disadvantaged [MDS], receiving

[3] KRÉTA is the national digital school administration platform used for operational records, while KIR is the official public education information system containing institutional and student-status statistics.

[4] It is important to emphasize that these teaching volume indicators are not self-reported estimates by principals. KRÉTA is the mandatory, state-run electronic administration and logging system used by all public schools in Hungary. Every scheduled and substituted lesson must be officially recorded here, providing highly reliable, administrative-level data on the actual teaching load.

regular child protection benefits [RCPB],[5] and students with integration, learning, and behavioural difficulties [ILBD][6]).[7] The demographic context was generated at the settlement level using census data, focusing on the population aged under 15 years in 2001 and 2022, and specifically the change between these two census years.

The primary analytical unit is the operational school site rather than a legal institution. This choice follows from the structure of the KRÉTA indicators: teaching volume, student headcount, and class structure are jointly interpretable at the level where teaching is actually organised. Settlement-level demographic variables were attached to school sites because demographic exposure, local cohort size, and administrative legal status are properties of the municipal environment in which sites operate. Institutions were assigned the administrative legal status of their settlement (village, town, large village, city with county rights, county seat, capital district), which approximates differences in settlement network role, organisational complexity, and service environment. For the mapping analysis only, site-level data were aggregated to the settlement level to analyse the spatial coincidence of teaching intensity and student-composition indicators.

[5] These administrative categories are strictly defined by Hungarian child protection law (Act XXXI of 1997 on the Protection of Children, Sect. 67/A). Disadvantaged (DS) and multiply disadvantaged (MDS) statuses are legal designations based on parental education levels, employment status, and housing conditions, which are structurally linked to the eligibility for regular child protection benefits (RCPB).

[6] ILBD corresponds to the Hungarian administrative category "beilleszkedési, tanulási és magatartási nehézség" (BTMN), which should not be treated as equivalent to statutory special educational needs categories in international comparison.

[7] All administrative extracts reflect the status of the databases as of November–December 2025.

Variables and indicator construction[8]

The central outcome variable of the study is the teaching load, primarily captured by the specific THPS indicator:

$$\textit{Teaching hours per student}_i = \frac{\text{Teaching volume}_i}{\text{Number of students}_i}.$$

The interpretation of this indicator is intuitive at the level of school-site operations: it expresses the volume of organised teaching capacity per enrolled student. Importantly, a higher THPS value does not imply that each student receives more scheduled instruction (e.g., attending more mathematics or literature lessons). Rather, it indicates that, relative to student headcount, the school site must organise and finance a higher volume of teaching hours to fulfil structural requirements. This may arise from additional group division, support-related lessons, or targeted provision, but it may also arise mechanically when nationally regulated grade-level and subject-level obligations are distributed across smaller classes. Thus, THPS is a measure of site-level teaching intensity, not a direct measure of individual student benefit, pedagogical quality, or teacher workload. In addition to teaching volume, we constructed two variables that describe the structure more directly to clarify the underlying mechanisms. First, the average class size:

$$\textit{Class size}_i = \frac{\textit{Number of students}_i}{\textit{Number of classes}_i},$$

Second, the teaching hours per class indicator:

$$\textit{Teaching hours per class}_i = \frac{\textit{Teaching volume}_i}{\textit{Number of classes}_i}.$$

[8] To improve transparency, descriptive statistics and full model specifications are reported in the Appendix. Appendix Table 1 presents the distribution of the main variables by administrative legal status, including student headcount, class size, teaching hours per class, THPS, demographic change and student-composition ratios. Appendix Table 2 reports the component models for class size and teaching hours per class. Appendix Table 3 reports the models linking THPS to structural variables and student-composition indicators. These tables allow the main text to focus on interpretation while keeping the empirical specification fully reproducible.

The relationship between these three indicators is established using a simple yet analytically useful identity:

$$\frac{\textit{Teaching volume}}{\text{Students}} = \frac{\text{Teaching volume/Classes}}{\text{Student/Classes}} = \frac{\text{Teaching hours per class}}{\text{Class size}}.$$

This allows us to distinguish whether a high teaching load results primarily from more hours allocated to a class or from fewer students per class (small class sizes, fragmented provision, and structural constraints).

The student composition was approximated by the proportions of the categories listed in the KIR database. Site-level values for DS, MDS, RCPB and ILBD were projected onto the KIR student headcount denominator (e.g., $DSratio_i = DS_i/students_i$).[9] Among the disadvantage indicators, the RCPB, DS, and MDS categories cannot be considered simple substitutes for one another, and they do not fully overlap; therefore, these student-composition categories were treated as separate variables rather than as a composite index. ILBD should not be treated as equivalent to statutory special educational needs (SEN) in international comparisons (Decree 15/2013 (II. 26.) of the Ministry of Human Capacities, 2013).[10]

This distinction is important for interpreting possible compensations. Statutory SEN categories may generate specific habilitation and rehabilitation lessons within the nationally regulated weekly timeframe, while ILBD and social disadvantage categories do not automatically translate into a proportional increase in teaching hours in the administrative data used here. Consequently, the association between THPS and student composition should be interpreted as spatial covariance between teaching intensity and recorded need-related categories, not as direct evidence that additional hours were allocated because of DS, MDS, RCPB or ILBD ratios.

The demographic environment was captured by the log-ratio change in the population aged under fifteen between 2001 and 2022:

$$\Delta\ln(\text{pop15}) = \ln\left(\frac{pop15_{2022} + 1}{pop15_{2001} + 1}\right)$$

where + 1 correction serves to handle the zero values and ensures numerical stability. The logarithm of the population aged under 15 years in 2022 was also included as a control. The site-level student headcount (institutional size) was log-transformed in the models, as the relationship between size and specific indicators is typically nonlinear across the entire range, and the log scale facilitates the interpretation of parameters.

Analysis plan: separating structural explanations and disadvantage compensation

The analysis strategy starts from the hypothesis that in lagging and demographically shrinking regions, the THPS ratio is often high not because the system actually allocates more hours to a class, but because relatively fixed mandatory teaching obligations are distributed across small classes and sites for structural reasons.

To assess this mechanism, we employed two complementary approaches. First, based on the relationship described above, we modelled class size and teaching hours per class separately as the two components of THPS. Estimating these components allows us to evaluate whether the association between demographic decline and higher THPS is more consistent with a class-size channel, interpreted as a structural mechanism, or with an increase in teaching hours per class, interpreted as a possible service adaptation. Second, we used regression models to examine whether the ratios of DS, MDS, RCPB, and ILBD were associated with THPS beyond structural factors such as site size and class size.[11]

[9] These categories reflect distinct administrative and entitlement logics, and their recorded prevalence may therefore capture different dimensions of disadvantage rather than a single underlying condition.

[10] ILBD differs legally and organisationally from statutory special educational needs (SEN). Under Act CXC of 2011, SEN mandates specific rehabilitation lessons typically provided by external travelling special education teachers, who operate within a distinct, separate institutional network. Conversely, ILBD interventions are usually managed internally by the school's own teaching staff.

[11] Addressing potential compensatory policies, Hungarian educational law treats special educational needs (SEN) and social disadvantages entirely differently in terms of resource allocation. For statutory SEN students (diagnosed by expert

Outcome variables were log-transformed, so the estimated coefficients can be interpreted as percentage changes. The teaching load at the site level was captured by the logarithm of the teaching volume projected per student:

$$Y_i = \ln\left(\frac{Teaching\ volume_i}{Students_i}\right) = \ln(Teaching\ volume_i) - \ln(Students_i)$$

The effect of the demographic trajectory was not interpreted through a single summary regression but by relying on the structural decomposition of the teaching load:

$$\frac{Teaching volume}{Students} = \frac{Teaching volume/Classes}{Students/Classes} = \frac{Teaching hours per class}{Class size}$$

Accordingly, we estimated two models with identical control structures: one explaining average class size (students/classes) and the other explaining teaching hours per class (teaching volume/classes). Based on the joint movement of these two components, it can be decided whether demographic decline contributes to the rise in THPS primarily through the decrease in class size (structural provision constraint) or through the increase in teaching hours per class (service surplus).

The demographic variable was recorded at the settlement level as the log-ratio change in the population aged under fifteen between 2001 and 2022:

$$\Delta\ln(pop15) = \ln(pop15_{2022} + 1) - \ln(pop15_{2001} + 1) = \ln\left(\frac{pop15_{2022} + 1}{pop15_{2001} + 1}\right)$$

We also controlled the size of the population aged under fifteen in 2022. The effect of institutional size was allowed to vary across three size ranges (under 150 students, 150–400 students, and over 400 students), reflecting the substantively different organizational logics of small, medium-sized, and large school sites.[12]

We illustrated the relationship between demographic trajectory and teaching load, as well as its differences by legal status, using the predicted values generated from the component models. The interpretation of demographic effects was demonstrated not merely by reporting coefficients but through predictive comparisons: we showed how the expected institutional scale and the resulting implied specific teaching load change by settlement type along the lower (p10) and upper (p90) ranges of the demographic distribution (strong decline vs. mild decline/growth).

Settlement aggregation and bivariate mapping

We constructed a settlement-level database to investigate the spatial patterns. For settlements with multiple sites, aggregation was performed on an additive basis to ensure a student-proximal interpretation of settlement indicators. For student-composition ratios,

Footnote 11 (continued)

committees), the law (Act CXC of 2011, Sec. 47) explicitly mandates additional weekly habilitation and rehabilitation teaching hours, which directly increases the institutional teaching volume. Furthermore, SEN students count as two or three students when calculating statutory class size maximums. In stark contrast, a high proportion of low-SES students—captured via administrative social disadvantage categories (DS, MDS, and RCPB)—does not automatically trigger a proportional, legally guaranteed increase in teaching hours or staffing within the basic state allocation formula. While highly disadvantaged schools might apply for targeted external grants or temporary developmental projects (e.g., after-school programs), their core teaching hour allocation remains primarily driven by the number of organized classes rather than the socioeconomic needs of the student body.

[12] The size thresholds were designed to reflect the organizational realities of Hungarian primary schooling rather than arbitrary statistical cut-offs. A full eight-grade school operating at the statutory minimum calculated class size of 14 students would imply approximately 112 students overall; however, institutions below roughly 150 students typically operate under persistent structural constraints, often involving combined classes and weak upper-grade enrolment. The upper threshold was intended to identify larger sites where year groups are commonly divided into at least two classes, implying a markedly different organizational logic from that of smaller and medium-sized institutions. This threshold should not be interpreted as a universal viability threshold, since school-size policies and minimum efficient scales vary considerably across national systems (Ares Abalde, 2014).

the settlement value was formed as the quotient of the sum of cases within the settlement and the sum of KIR students. The settlement-level THPS indicator was calculated analogously as the sum of teaching volume divided by the sum of students, which behaves as a student-weighted average and avoids the bias that would arise if a small site carried the same weight as a large one.

To check the robustness of the spatial patterns, we applied the Global Moran's I indicator for disadvantage ratios (DS, MDS, ILBD, RCPB), using a queen contiguity weight matrix and row standardisation in an ArcGIS Pro environment. This allowed for testing the significance of positive autocorrelation (clustering) ($p < 0.001$), supporting the cumulative nature of lagging regions.

The covariance of the settlement teaching load and status ratios was illustrated using bivariate thematic maps in ArcGIS Pro. The bivariate legend consisted of two dimensions: the blue component representing THPS and the orange component representing the given status ratio (DS, MDS, RCPB, or ILBD). Both dimensions were classified into three levels (low, medium, and high) based on Jenks Natural Breaks, and the combination of the two classifications (3×3) was mapped. The map patterns were supported by cross-tabulations showing the proportion of settlements with high-status ratios falling into the high teaching-load range and, conversely, the proportion of settlements with high teaching loads possessing high-status ratios.

Results

Structural components of specific teaching load and demographic correlations

Class size: the primary channel of structural constraint

Based on raw distributions, institutional and class sizes show significant disparities even at the descriptive level. The median number of students was 160 in villages (interquartile range [IQR]: 123–211), 401 in towns (IQR: 303–556.5), 391.5 in capital districts (IQR: 298–486.25), and 445 in county seats (IQR: 354.5–561.5). In parallel, the median class size is 17.88 in villages (IQR: 15.38–20.09), 21.06 in towns (IQR: 19.29–23.45), 22.72 in capital districts (IQR: 20.05–24.63), and 23.17 in county seats (IQR: 21.00–24.72). The pattern suggests that a smaller school-site scale is typically associated with a lower class size.

The relationship between specific teaching load and class size is remarkably strong and inverse: the Pearson correlation coefficient between the log-transformed indicators is $r = -0.781$. This means that when the class size is smaller, the specific THPS value is higher.

The component models (controlling for legal status and using a nonlinear specification for institutional size) also clearly indicate a demographic correlation in the case of class size: the estimated coefficient for $\Delta\ln(pop15)$ is $\beta = 0.0799$ ($p < 0.001$), with a model fit of $R^2 = 0.638$. In other words, a more favourable demographic trajectory (higher $\Delta\ln(pop15)$ is associated with an increase in class size, while decline $\Delta\ln(pop15)$ is associated with a reduction in class size.

The magnitude of demographic differences can be quantified, even for typical institutional sizes. Comparing the p10 (strong decline) and p90 (mild decline/growth) cases while holding institutional size constant, class size is approximately 5.08% lower in the p10 case (Fig. 1).

Teaching hours per class: limited demographic adaptation

The levels of teaching hours per class are also differentiated by legal status, but demographic sensitivity is lower here. The median teaching hours per class were 42.21 in villages (IQR: 39.13–45.56), 45.59 in towns (IQR: 42.44–49.07), 49.00 in capital districts (IQR: 46.77–51.83), and 49.44 in county seats (IQR: 47.16–52.07). Thus, in higher-status administrative environments with larger institutions, teaching volume per class is typically higher.

However, the relationship between teaching hours per class and THPS is significantly weaker than that of class size: the correlation of log-transformed indicators is $r = 0.155$. In the estimated component model, the effect of the demographic variable was small and statistically unconvincing: $\beta = 0.0161$ ($p = 0.208$), $R^2 = 0.293$. This indicates that the teaching volume per class does not closely follow the settlement's demographic trajectory over time (Fig. 2).

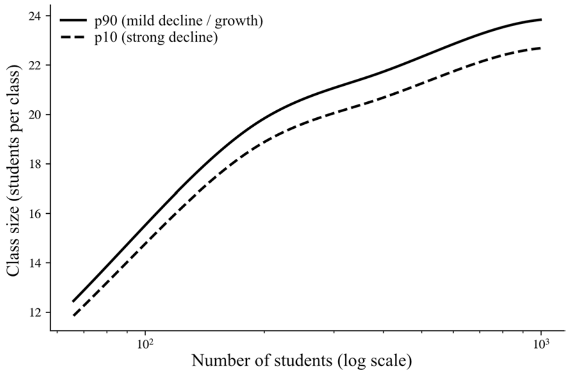

Fig. 1 Class size as a function of student headcount and demographic trajectory (p10 = strong decline, p90 = mild decline/growth; 95% confidence interval)

Specific teaching load (Teaching Hours per Student): the resultant effect of small-scale structure

The levels of specific teaching loads were consistent with the structural picture. The median THPS was highest in villages (2.379; IQR: 2.111–2.735), whereas it was lower in towns (2.127; IQR: 1.956–2.380) and county seats (2.161; IQR: 1.978–2.466). The median for capital districts was 2.168 (IQR: 2.001–2.460). These differences indicate that different specific teaching load levels are associated with different institutional scales in the socio-spatial space.

The deviation between demographically defined cases remains visible even at identical institutional sizes: in the p10 case, the implied THPS is approximately 4.25% higher at the examined size points.

Reading the components together suggests a consistent structural pattern. Regarding demographic decline, the predicted reduction in class size is approximately 5.08%, while the corresponding difference in teaching hours per class is approximately 1.05%. Therefore, the implied THPS shifts upward, mainly because similar organisational obligations are distributed across smaller classes. These results support the interpretation that the primary observed channel between the demographic trajectory and THPS is the small-class structure, rather than a systematic increase in teaching volume per class (Fig. 3).

System of relationships by administrative legal status

Demographic trajectory correlates with the level of specific teaching load not only at identical institutional sizes (as seen in the previous subsection) but also through the expected institutional scale. To illustrate this, we describe the differences between administrative legal statuses in a two-step system of relationships: (1) the relationship between demographic change and expected school size, and (2) the relationship between demographic change and the level of implied THPS.

First, we established the relationship between demographics and expected school size by legal status of the school (Fig. 4). The estimation results show that between the p10 (strong decline) and p90 (mild decline/growth) cases, a substantial shift in the

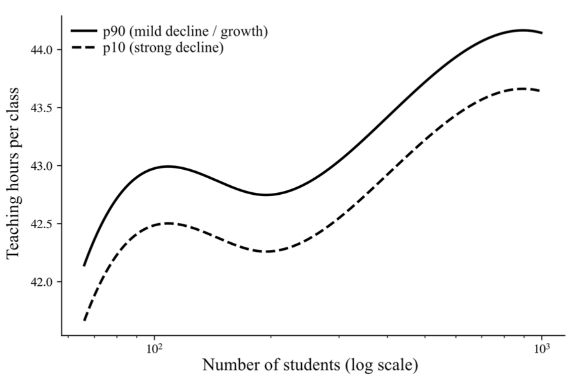

Fig. 2 Teaching hours per class as a function of student headcount and demographic trajectory (p10 = strong decline, p90 = mild decline/growth; 95% confidence interval)

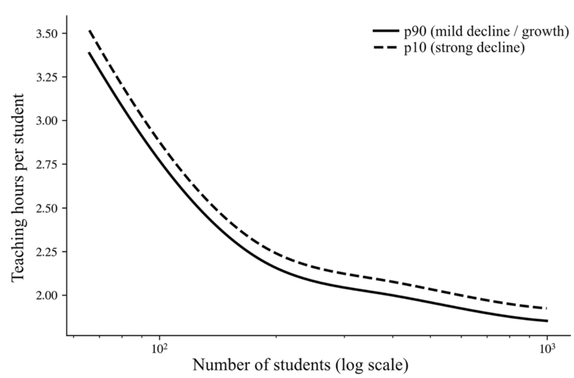

Fig. 3 Teaching hours per student as a function of student headcount and demographic trajectory (p10 = strong decline, p90 = mild decline/growth; 95% confidence interval)

expected student headcount is observable across several legal statuses.

For village sites, the expected school size is 157.161 in the p10 case, compared to 169.468 in the p90 case (difference: –7.26%). In towns, the difference is larger: 369.025 (p10) vs. 439.859 (p90), representing a –16.10% deviation from the expected value. In the case of county seats, the p10–p90 difference is particularly marked: 385.898 vs. 563.230 (–31.49%), while in cities with county rights, it is 344.943 vs. 518.870 (–33.52%). Thus, the curves indicate that demographic decline is associated with a significant shrinkage of the expected institutional scale in urban and higher legal status categories.

However, the two legal status categories yield a different p10–p90 pattern: in capital districts, the expected school size is 383.135 (p10) vs. 352.765 (p90), that is, + 8.61%, and in large villages, it is 252.859 vs. 247.693, that is, + 2.09%. Consequently, the overall picture of the curves by legal status records not only shows level differences but also differing demographic slopes.

Second, we present the relationship between demographic trajectory and implied THPS by legal status (Fig. 5). The curves show a pattern in the same direction for every legal status category: moving toward demographic decline (toward p10), the specific teaching load increases. The p10–p90 differences developed as follows: in villages 2.459 (p10) vs. 2.323 (p90), which is + 5.82%; in towns 2.162 vs. 2.037 (+ 6.13%); in county seats 2.217 vs. 2.097 (+ 5.72%); in large villages 2.248 vs. 2.165 (+ 3.82%); and in capital districts 2.238 vs. 2.182 (+ 2.54%). In the category of cities with county rights, the difference is 2.172 vs. 2.013 (+ 7.93%).

Based on the comparison of data, the village category is situated in a higher specific teaching load range even at the same demographic point: even in the more favourable (p90) demographic cases, the value is 2.323, while the town p90 value is 2.037, the county seat p90 value is 2.097, and that of capital districts is 2.182. Thus, differences between legal statuses appear not only in demographic slopes but also in the baseline level of specific teaching loads.

Overall, our results indicate that demographic decline is associated with a smaller expected institutional scale in most legal statuses, and specific teaching load shifts to a higher level in the direction of decline across all legal status. Differences between legal statuses are particularly evident in the demographic sensitivity of the expected institutional scale (Fig. 4) and the baseline level of specific teaching load (Fig. 5).

Spatial covariance of disadvantage indicators (DS, MDS, and RCPB), ILBD, and teaching load at the settlement level

We grounded the exploration of spatial patterns by examining Global Spatial Autocorrelation (Global

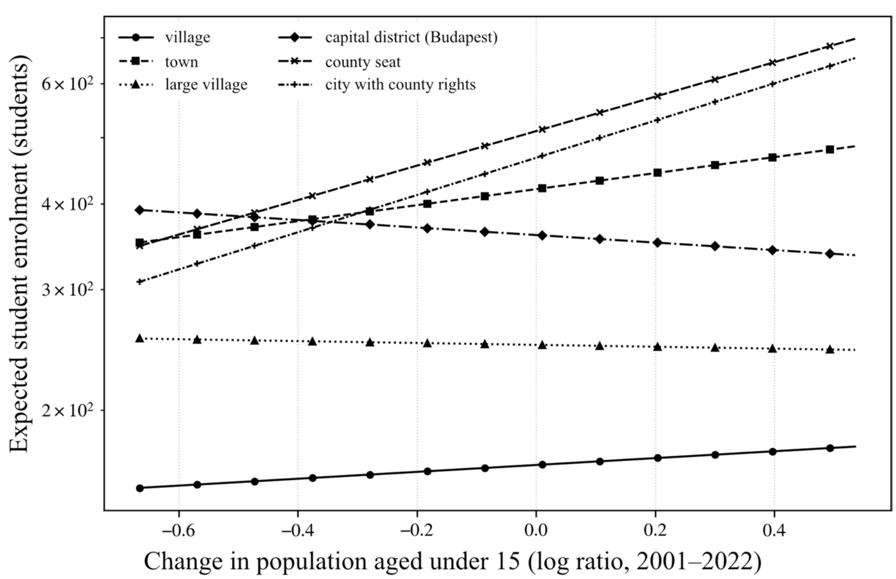

Fig. 4 Relationship between demographic trajectory and expected school size by administrative legal status (p10 = strong decline, p90 = mild decline/growth; logarithmic scale on the student headcount axis)

Moran's I). The analysis confirmed significant ($p < 0.001$) positive autocorrelation, that is, spatial clustering stronger than random clustering, for every disadvantage indicator. The strongest spatial concentration is observed for the proportion of students receiving RCPB ($I = 0.531$; $z = 19.71$) and multiply disadvantaged students ($I = 0.490$; $z = 18.22$), while the clustering of disadvantaged students ($I = 0.376$; $z = 13.97$) is more moderate.

Based on indicators aggregated to the settlement level, we examined the extent to which administrative categories indicating student composition (DS, MDS, RCPB) and the ILBD ratio aligned with the teaching load (THPS). The interpretation of spatial patterns is aided by bivariate (dual) classification: the blue component represents the teaching load, the orange component represents the given status ratio (DS/MDS/RCPB/ILBD), and the category combinations of the two dimensions collectively indicate where high teaching load and high disadvantage or ILBD ratio are concentrated.

According to the settlement frequencies of the bivariate classification, the number of examined settlements was $N = 1092$. In the teaching load dimension, the majority of settlements fell into the middle category (Q2): 852 settlements (78%), while 240 settlements (22%) were in the high teaching load category (Q3). This means that a high teaching load is not a marginal phenomenon: roughly one in five settlements falls into the upper teaching load range. The low teaching load category (Q1) does not appear in the cross-tabulations; thus, the interpretation of covariance with status ratios relies substantially on shifts between the middle and high teaching load ranges.

The relationship between the DS ratio and teaching load shows a particularly marked gradient pattern. Among the settlements with a low DS ratio (Q1), 84 out of 618 cases belonged to the high teaching load category (13.6%). Among settlements with a medium DS ratio (Q2), 103 out of 337 cases had a high teaching load (30.6%), while among settlements with a high DS ratio (Q3), 53 out of 137 cases fell into the high teaching load range (38.7%). In other words, with an increase in the DS ratio, the settlement-level occurrence of a high teaching load rises threefold compared to the low DS ratio group, indicating a strong association between the settlement student composition and the volume of teaching service per student.

In the case of MDS, the direction of the relationship is similar, although it is more moderate. Among settlements with a low MDS ratio (Q1), 166 out of 848 cases had a high teaching load (19.6%); for settlements with a medium MDS ratio (Q2), 52 out of 181 (28.7%); while among settlements with a high MDS ratio (Q3), 22 out of 63 (34.9%) belonged to the high teaching load category. The tendency is thus rising here as well, but less "steep" compared to DS, suggesting that MDS, as a narrower, more strongly selective disadvantage indicator, rearranges the distribution of settlements by teaching load to a lesser extent.

The covariance of the RCPB ratio and teaching load produced a powerful gradient pattern very close to that of DS. Among settlements with a low RCPB ratio (Q1), 88 out of 641 cases had a high teaching load (13.7%). Among settlements with a medium RCPB ratio (Q2), 89 out of 291 (30.6%), while among settlements with a high RCPB ratio (Q3), 63 out of 160 (39.4%) belong to the high teaching load category. Similar to DS, we see here that a high teaching load is much more frequent in settlements with high status ratios, making a closer co-movement of settlement-level service burden and social-type status indicators probable.

In contrast, a nonlinear "U-shaped" shift is observable in the case of the ILBD ratio. Among settlements with a low ILBD ratio (Q1), 37 out of 146 cases had a high teaching load (25.3%); for settlements with a medium ILBD ratio (Q2), 142 out of 748 (19.0%); while among settlements with a high ILBD ratio (Q3), 61 out of 198 (30.8%) belonged to the high teaching load category. Compared with the middle ILBD ratio, a high teaching load was more frequent in both low- and high-ILBD ratio settlements. This pattern differs from the monotonically rising relationship seen with DS/MDS/RCPB and suggests that the settlement-level occurrence of ILBD may be organised according to different logics (e.g. due to territorial differences in identification, registration, and access to the care system). Therefore, the interpretation of the covariance between ILBD and teaching loads requires a more cautious approach.

Based on the cross-tabulations, in the case of DS and RCPB ratios, the settlement-level probability of high teaching load shows a clear increasing gradient with the increase in status ratio, while for MDS, the

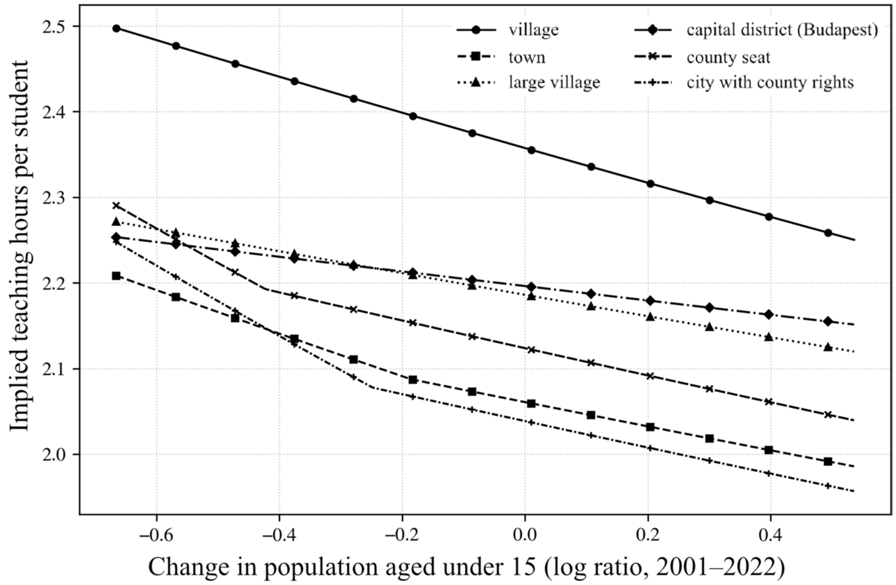

Fig. 5 Relationship between demographic trajectory and implied teaching hours per student by administrative legal status (p10 = strong decline, p90 = mild decline/growth)

direction of the relationship is identical but weaker. In the case of ILBD, the relationship is not monotonic but differentiated: a high teaching load does not simply "grow together" with the ILBD ratio but is more frequent in the extreme ranges compared to the middle ILBD range. The bivariate maps visually reinforce this picture: on the DS and RCPB maps, settlements where high teaching loads and high status ratios concentrate in the same spatial units appear in greater proportions, whereas the ILBD map presents a more heterogeneous image (Fig. 6).

Discussion

This study examined how demographic decline and the spatial concentration of social disadvantage jointly shape the uneven teaching intensity and local service pressure in public primary education. Our results indicate that a spatially uneven "double pressure" is empirically observable: institutions operating in lagging regions simultaneously struggle with pedagogical challenges arising from unfavourable student composition and higher specific operational burdens resulting from demographic shrinkage.

Demographic decline and the structural constraint of teaching intensity

Consistent with hypothesis [H1], demographic decline was associated with higher site-level teaching hours per student. This pattern is more consistent with the structural constraints of small-scale provision than with a simple interpretation of reduced pedagogical efficiency. However, because the analysis does not include direct expenditure, staffing quality, or classroom-process indicators, this interpretation should be read as structural and inferential rather than causal.

This result aligns with the international literature describing the educational challenges of "shrinking spaces" through the tension between capacity and access (Béres, 2025; Haase et al., 2016). In settlements with declining populations—often villages—maintaining local primary school provision may require higher per-student teaching intensity because several grade-level and subject-level obligations remain weakly adjustable. This is consistent with economies-of-scale arguments in education, according to which small-scale provision tends to display less favourable per-unit indicators when fixed or semi-fixed organisational requirements are distributed across fewer pupils (Blank & Niaounakis, 2019; Riew, 1966). At the same time, smaller classes may also support more personalised instruction and may carry pedagogical benefits (Finn, 2019; Jepsen &

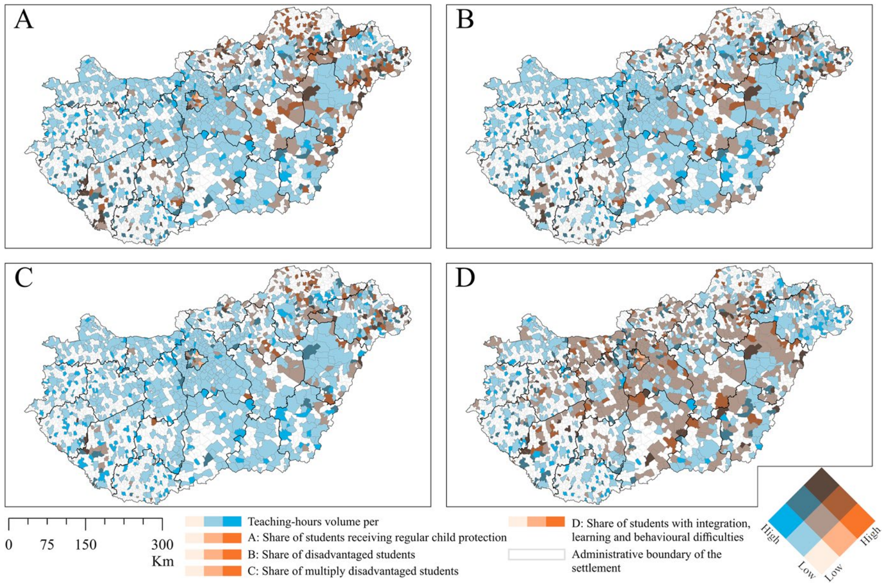

Fig. 6 Bivariate maps of settlement teaching load (teaching hours per student; blue component) and status ratios (orange component). (**a**) RCPB ratio × teaching load, (**b**) DS ratio × teaching load, (**c**) MDS ratio × teaching load, (**d**) ILBD ratio × teaching load. The bivariate legend displays category combinations of the two dimensions; darker tones indicate the co-occurrence of a high teaching load and high status ratio

Rivkin, 2009). However, falling below a critical minimum class size can also present severe pedagogical disadvantages. An extremely fragmented, small-scale peer environment limits the diversity of social interactions, collaborative learning opportunities, and the broader development of social competencies essential for community building. Therefore, the observed pattern should be interpreted as a structural trade-off between local access, organisational scale, and possible pedagogical opportunities rather than as a direct measure of inefficiency.

The component analysis also supported [H2]: the increase in specific teaching load was driven by shrinking class size rather than by higher teaching hours per class. This pattern reflects the "capacity stress" described in the literature: rural schools must maintain minimum organizational and staffing structures even under declining enrolment, which limits proportionate scale adjustment (Andl, 2021; Kolbe et al., 2021; Rude & Miller, 2018). While consolidating these shrinking school sites might seem like a logical administrative solution to improve efficiency, such measures are fundamentally limited by spatial constraints. As recent spatial evaluations of primary education highlight, travel distance and commuting time remain critical determinants of school accessibility (Meena et al., 2022). Therefore, in shrinking settlements, the structural necessity of maintaining smaller classes is deeply tied to the fact that consolidation would drastically increase commuting burdens, thereby compromising physical access to education.

Spatial intertwining of social disadvantage and teaching intensity

Consistent with [H3], higher specific teaching load tended to cluster in settlements with greater social disadvantage, suggesting that educational and service burdens accumulate spatially. This pattern fits research examining educational inequalities in lagging regions and peripheries (Pénzes et al., 2023; Béres et al., 2025). This overlap may also reflect a broader residualisation process in which long-term population decline is accompanied by the selective out-migration of more mobile and better-resourced households. As a result, shrinking settlements may simultaneously face declining school-age cohorts, weaker local human-capital resources and a higher relative concentration of social disadvantage (Ouředníček et al., 2011; Tagai et al., 2018; Ubarevičienė & van Ham, 2017).

Where high THPS meets unfavourable student composition, the issue is not only operational but also spatially just provision. From a spatial justice perspective, the central question is whether the system can maintain reasonable territorial access while also responding to unequal local needs. High THPS in shrinking settlements may indicate the organisational cost of preserving access, but it does not automatically mean that pupils receive compensatory pedagogical benefits. This distinction is crucial: without targeted support, the same teaching intensity may function as passive structural cost in one place and as active compensation in another. Our results therefore reinforce the findings of Velkey (2022) and Hegedűs (2016a, 2023) regarding the replication of territorial and social inequalities, while also highlighting spatial non-stationarity: the same institutional resource may function differently in a disadvantaged shrinking village than in a stable urban setting (Sacco & Falzetti, 2021).

The ILBD paradox: access and diagnostics

The "U-shaped" relationship between the proportion of ILBD students and teaching load, which appeared in the results, though not in our hypotheses, deserves special attention. While social indicators (DS, RCPB) followed the load linearly, in the case of ILBD, we measured higher proportions at both extremes compared to medium-provisioned regions. This phenomenon can be interpreted through "gatekeeping" mechanisms discussed in the literature (Keating et al., 2025) and inequalities in access to diagnostics (Halvorsen et al., 2025).

One possible interpretation is that, in higher-status school environments, parents may be better positioned to navigate diagnostic and support systems, while in more disadvantaged regions a high ILBD ratio may partly reflect accumulated social and pedagogical difficulties as well as uneven access to early identification and support. However, the present data do not allow for direct observation of the diagnostic pathways. Therefore, the findings should be interpreted cautiously: the spatial pattern of ILBD is unlikely to be purely needs-driven, but the relative role of need, diagnosis, parental advocacy, and institutional capacity cannot be disentangled within the current design. This interpretation is consistent with studies emphasising the social and territorial embeddedness of special-needs identification and service access (Rohrer et al., 2019; Sturm et al., 2021).

Limitations

This study had several limitations. First, the analysis uses administrative and cross-sectional site-level data and, therefore, identifies structural associations rather than causal effects. The results should not be interpreted as showing that demographic decline mechanically causes higher THPS in every local context; rather, they show that demographic shrinkage, smaller class size, and higher site-level teaching intensity are systematically associated in the observed administrative data.

Second, THPS is an operational indicator of teaching intensity, not a direct measure of expenditure, pedagogical quality, teacher workload, or student-level benefit. A higher value may reflect a small-class structure, group division, additional support-related lessons, or other organisational arrangements; however, the available data do not allow these components to be fully separated. The indicator also does not capture teacher shortages, teacher qualifications, lesson substitution, classroom processes, or the quality of support provided.

Third, the use of settlement-level aggregation for mapping may smoothen the differences between school sites within the same municipality. It is suitable for analysing settlement-level spatial exposure, but it cannot identify the historical effects of school closures, mergers, or the loss of the last school in a settlement. These closure and "last school" effects are important governance and spatial justice issues, but they are not directly operationalised in the present dataset. Moreover, school closure should not be interpreted as a direct or automatic cause of local depopulation, since the relationship between closure and demographic decline is context-dependent (Barakat, 2015).

Fourth, the governance context is only partially considered. The analysis distinguishes administrative legal status and settlement-level demographic context, but it does not directly measure maintainer decisions, local political conflicts, catchment area changes, or the professional deliberations behind class organisation. Consequently, political and planning mechanisms are discussed as part of the explanatory framework but are not estimated as separate empirical variables.

Fifth, the student composition categories are administrative. DS, MDS, and RCPB capture different entitlements and social policy logics, while ILBD reflects an administrative-diagnostic category that may depend on access to assessment, parental advocacy, and institutional capacity. ILBD should not be treated as equivalent to statutory SEN in international comparisons. Therefore, this study interprets these variables as recorded student-composition indicators rather than exhaustive measures of underlying needs.

Finally, the bivariate maps are both exploratory and illustrative. Their categories depend on the selected classification method and should not be considered normative thresholds. Future research should combine longitudinal school-site histories, closure data, staffing indicators, and student-level outcomes to test more directly whether high teaching intensity in shrinking regions functions as a passive structural cost or as an active compensatory provision.

Conclusion

Based on our results, the simultaneous presence of demographic decline and concentrated disadvantage in the territorial system of Hungarian public education creates an operating environment in which conventional organisational responses face important limitations, particularly in the post-2013 context of centralised state maintenance. For school sites under "double burden," high THPS should not be interpreted automatically as an efficiency problem. It may also represent the structural cost of maintaining local access under conditions of low enrolment and small class size.[13]

Regarding potential solutions, the literature highlights resource integration, networking, and clustering as pledges of sustainability for rural education. Simultaneously, as emphasised by Zhu and Li (2025) and Lan (2025), educational equity demands targeted, place-specific resource allocation. The policy challenge is therefore to ensure that structurally elevated teaching intensity is not left as a passive organisational cost but is connected, where possible, to visible pedagogical support for students. Thus, the results suggest that a more strategic use of existing capacities could form part of a place-sensitive policy response, although the present analysis cannot determine the staffing or budgetary requirements of such interventions.

In the Hungarian context, this means that in demographically shrinking but socially burdened regions, the currently elevated specific indicator, which reflects the structural cost of smaller class sizes, should be more explicitly connected to active pedagogical support where organisational conditions allow. The policy challenge is therefore to ensure that structurally elevated teaching intensity is not left as a passive organisational cost, but is connected, where possible, to visible pedagogical support for students.

As a policy implication, the results point toward the need to connect existing teaching capacity more explicitly to the targeted support. Since high THPS in shrinking and disadvantaged settlements does not automatically translate into effective compensation for educational inequalities (Custers et al., 2023; Fleming & Harford, 2023). Instead of merely observing structural inputs, policy responses must examine whether this organised capacity is genuinely converted into visible, on-the-ground pedagogical support (Xiang & Stillwell, 2023). Overcoming spatial and structural constraints necessitates network-based service delivery models, including itinerant teachers and travelling specialists (Rude & Miller, 2018), shared services through inter-site provision (Han & Xie, 2025; Wang et al., 2019), and equitable access through organised school transport (Rohrer et al., 2019). Low student numbers may also create opportunities for personalised mentoring and closer student follow-up, but only if organisational conditions, professional support, and governance instruments make such use feasible. In the smallest and most fragile settings, policy responses may also need to include coordinated inter-site provision, shared specialist services, and, where locally appropriate, organised student transport to reconcile educational quality with territorial equity.

Overall, the central dilemma is not simply whether small schools should be closed or preserved, but whether the high per-student teaching intensity arising from demographic constraints can be connected to genuine pedagogical compensation or not. The educational double burden of lagging regions is therefore not merely a resource-allocation question but also a spatial justice issue: targeted and place-sensitive

[13] In the Hungarian context, these tensions unfold within a highly centralized governance environment, where local institutions face limited room for autonomous adjustment even when demographic shrinkage and concentrated disadvantage coincide.

interventions are needed if local access is to be maintained without reproducing territorial inequality.

Seen in this way, the geography of educational burden is also a geography of uneven state presence: some places bear the cost of maintaining accessibility under demographic decline far more heavily than others do.

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Author's contribution A.B. conceptualized the study, performed the formal analysis, interpreted the findings, and wrote the manuscript. B.P. contributed to the development of the research design, supported the acquisition of the data, reviewed the results, and provided critical comments on the manuscript. Both authors reviewed and approved the final manuscript.

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Data availability The datasets analysed during the current study are not publicly available due to administrative data-use restrictions; however, aggregated data and information on the KIR database is available at https://kir.oktatas.hu/

Declarations

Conflict of interest The authors declare no competing interests.

Ethical approval Not applicable.

Appendix

See Tables 1, 2 and 3.

Table 1 Descriptive statistics by administrative legal status

Administrative legal status	Number of school sites	Median student headcount	IQR student headcount (Q1–Q3)	Median class size	IQR class size (Q1–Q3)	Median teaching hours per class	IQR teaching hours per class (Q1–Q3)	Median THPS	IQR THPS (Q1–Q3)	DS ratio (mean)
Village	680	160	123.0–211.0	17.875	15.38–20.09	42.207	39.12–45.56	2.379	2.111–2.735	0.135
Large village	87	232	183.0–350.5	19.333	17.44–21.38	42.750	39.80–45.03	2.225	2.039–2.438	0.156
City	418	401	303.0–556.5	21.065	19.29–23.45	45.586	42.44–49.07	2.127	1.956–2.380	0.078
City with county rights	33	484	366.0–549.0	22.286	20.05–24.39	47.750	46.12–50.68	2.204	1.962–2.406	0.026
County seat	175	445	354.5–561.5	23.167	21.00–24.72	49.438	47.16–52.07	2.162	1.978–2.466	0.024
Capital district	208	392	298.0–486.2	22.721	20.05–24.62	49.000	46.77–51.83	2.168	2.001–2.460	0.011

Administrative legal status	DS ratio (median)	MDS ratio (mean)	MDS ratio (median)	RCPB ratio (mean)	RCPB ratio (median)	ILBD ratio (mean)	ILBD ratio (median)	Δln(U15) 2001–2022 (mean)	Δln(U15) 2001–2022 (median)
Village	0.079	0.134	0.032	0.242	0.109	0.139	0.127	−0.195	−0.213
Large village	0.114	0.128	0.055	0.274	0.165	0.125	0.128	−0.203	−0.226
City	0.042	0.078	0.022	0.152	0.076	0.134	0.125	−0.221	−0.298
City with county rights	0.015	0.012	0.006	0.055	0.040	0.124	0.112	−0.264	−0.297
County seat	0.013	0.020	0.006	0.051	0.027	0.116	0.111	−0.289	−0.263
Capital district	0.004	0.006	0.000	0.027	0.012	0.140	0.132	−0.077	−0.038

Student headcount uses KRÉTA student headcount when available (fallback to KIR_student). THPS (teaching hours per student) = teaching volume (source: KRÉTA) divided by student headcount. Demographic change is $\Delta\ln(U15) = \ln(U15_{2022+1})$—$\ln(U15_{2001+1})$

Table 2 Component models of THPS

Covariate	Model 1: ln(class size)	Model 2: ln(teaching hours per class)
Legal status: Capital district (ref. = Village)	−0.003 (0.022)	0.118^{***} (0.021)
Legal status: Large village (ref. = Village)	−0.016 (0.016)	−0.004 (0.013)
Legal status: County seat (ref. = Village)	0.009 (0.024)	0.124^{***} (0.024)
Legal status: City with county rights (ref. = Village)	0.004 (0.029)	0.068^{*} (0.035)
Legal status: City (ref. = Village)	−0.011 (0.013)	0.049^{***} (0.012)
Intercept	0.007 (0.458)	2.701^{***} (0.621)
$\Delta\ln(U15)$ 2001–2022	0.080^{***} (0.013)	0.016 (0.013)
$\ln(U15_{2022+1})$	0.016^{*} (0.007)	0.006 (0.006)
ln(site size) segment 1	0.572^{***} (0.095)	0.214 (0.135)
ln(site size) segment 2 (knot = 150)	-0.370^{***} (0.108)	−0.210 (0.146)
ln(site size) segment 3 (knot = 400)	-0.153^{***} (0.026)	0.026 (0.026)
N	1601.0	1601.0
R^2	0.638198	0.293373
Adj. R^2	0.635923	0.288929

OLS with HC3 robust standard errors. Coefficients are shown with standard errors in parentheses. Significance: $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$. Site-size spline uses log(student headcount) with knots at 150 and 400 students. Reference category for legal status: village

Table 3 THPS model with student-composition indicators

Covariate	Model 3: ln(THPS)
Intercept	2.756*** (0.622)
Legal status: City (ref. = Village)	0.046*** (0.012)
Legal status: Large village (ref. = Village)	0.004 (0.012)
Legal status: Capital district (ref. = Village)	0.103*** (0.022)
Legal status: County seat (ref. = Village)	0.111*** (0.025)
Legal status: City with county rights (ref. = Village)	0.053 (0.032)
ln(site size) segment 1	0.083 (0.124)
ln(site size) segment 2 (knot = 150)	−0.125 (0.136)
ln(site size) segment 3 (knot = 400)	0.064* (0.025)
ln(class size)	−0.791*** (0.033)
Δln(U15) 2001–2022	−0.010 (0.013)
$\ln(U15_{2022+1})$	0.002 (0.006)
DS ratio	-0.058 (0.035)
MDS ratio	−0.114*** (0.026)
RCPB ratio	0.005 (0.024)
ILBD ratio	0.172*** (0.049)
N	1601.0
R^2	0.672545
Adj. R^2	0.669446

OLS with HC3 robust standard errors. Coefficients are shown with standard errors in parentheses. Significance: $^{*}p<0.05$, $^{**}p<0.01$, $^{***}p<0.001$. Site-size spline uses log(student headcount) with knots at 150 and 400 students. Reference category for legal status: village

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